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AN EVALUATION OF THE EFFECTIVENESS OF SNTI,
AN INTEGRATED SHIPBOARD COMMUNICATIONS SYSTEM,
FOR USE ABOARD U.S. NAVY SURFACE COMBATANTS

by

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An Evaluation of the Effectiveness of SNTI, an Integrated Shipboard Communications System, for Use Aboard U.S. Navy Surface Combatants

by

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requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS MANAGEMENT

ABSTRACT

Shipboard Interior Communication (IC) systems, a critical part of command and control, have not kept pace with the technological advances occurring in other areas of Naval warfare. As a result, the requirements and demands placed on an IC system in a warfare scenario are not likely to be met with much success. This thesis to takes the first steps towards rectifying this unsatisfactory situation. The general weaknesses and problems with present IC systems are identified. Then, paying close attention to the needs of surface combatants, particularly DDG-51 and FFG-7 class ships, the requirements and functions needed to improve shipboard IC are presented. These are incorporated into the requirements and functions needed to develop an ideal Integrated Shipboard Communication System (ISCS). A French designed and built ISCS is then compared to this ideal system in order to evaluate its potential for implementation aboard U.S. Navy surface combatants.

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I. INTRODUCTION

A. PURPOSE/OBJECTIVES

In the everchanging, highly volatile, intense tempo of today's naval warfare scenarios, the ability to communicate successfully and efficiently is more critical than ever before. The failure of a ship to communicate, either internally or externally, would probably result in a mission failure at the very least and quite possibly the destruction of that ship in a hostile situation.

Therefore, this thesis will attempt to look at where we stand with today's Integrated Shipboard Communication Systems (ISCS) and what can be done to improve upon our present condition. The area of research will be to analyze the ISCS capabilities of present U.S. Navy surface combatants, placing special emphasis on the Oliver Hazard Perry, FFG-7, class and on the Arleigh Burke, DDG-51, class ships. A majority of the research will be an analysis of the Systeme Numerise de Transmissions Interieures (SNTI) ability to match or exceed these capabilities. The SNTI is an integrated shipboard communications system developed by the French for use aboard their Naval surface combatants. As a result, the thrust of this study will be aimed at determining the ISCS requirements on FFG-7 and DDG-51 ships and the capabilities of the SNTI with respect to these requirements. This thesis will examine the weaknesses of present ISCS and look at how well the SNTI eliminates them.

The result of this research and the goal of this thesis is to provide the answers to the following two questions:

1. What are the requirements for an ISCS aboard U.S. Navy surface combatants?
2. How effective is SNTI in meeting these requirements?

In answering these questions it was determined that an in-depth analysis of the external communication requirements and capabilities of these ships was beyond the scope of this thesis. To attempt to include them would be detrimental to providing accurate and viable answers to the research questions posed. Therefore, the assumption is made that the external communication capabilities of these ships are considered adequate for the purpose of this thesis. This assumes that the necessary frequencies, channels, transmitters and receivers are available to the shipboard users or operators. As a result, the ISCS being evaluated will be critiqued on its ability to interface with these available circuits.

B. BACKGROUND

It has been consistently observed that major Command, Control and Communication (C^3) problems aboard ship today revolve around the inadequacies of installed ISCS. Poor response time in defending the ship, delays in establishing communications (both internal and external) and the inadequate dissemination of critical information are just a few of the resulting problems. These problems and others occur due to the inability of most systems to adapt to changing scenarios and to respond to increases in demand in a timely and efficient manner.

New technological advances have resulted in a number of new weapon systems and an increased offensive capability that have drastically reduced a ship's defensive response time down to a matter of seconds in some instances. These technological improvements combined with the continued increase in the volume and complexity of ocean surveillance, as well as the tactical information associated with these new weapons and sensors places an increasingly heavy burden on shipboard C^3 systems, including information transfer rates. The primary data stress points fall on interior

voice communications (IC) between watch and battle stations. This problem is further complicated by the increasing technical sophistication of own force weapon and sensor systems and the associated communications necessary to employ these systems in a timely manner.

C. METHODOLOGY

This thesis will attempt to uncover the weaknesses of today's systems that cause these problems and what capabilities are required of a new system to eliminate such difficulties. The overall approach will consist of the following general steps:

1. Identify the missions of U.S Naval surface combatants with special emphasis on FFG-7 and DDG-51 class ships.
2. Briefly describe the impact of new, technologically advanced weapon and detection systems on present ISCS.
3. Identify the shortcomings of the ISCS installed aboard FFG-7 and DDG-51 class ships.
4. Describe the features of an ISCS that would help eliminate the inadequacies present in current systems.
5. Describe the capabilities and features of SNTI. Evaluate the ability of SNTI to eliminate the weaknesses identified earlier.
6. Provide conclusions and recommendations with respect to the effectiveness of SNTI for use by the U.S. Navy.

The analysis of the research questions will be based on a thorough review and examination of the information gathered from appropriate articles and references used in conducting the research. The analysis will also include judgements and critiques based on personal experiences as well as from informal conversations with other Naval officers and experts in this field. Thus, using the knowledge gained, the requirements of and demands on an ISCS will be presented. The strengths and weaknesses of present systems will then be identified. Then, based on the information gathered, assumptions made and evaluations rendered a hypothetical, ideal system will be defined. The effectiveness of SNTI in meeting the capabilities of this ideal system will then be examined.

This evaluation will include an analysis of SNTI's functional capabilities, design criterion and its ability to meet pre-determined human factors considerations. Also included will be an examination of system effectiveness regarding vulnerability costs and cost performance analysis. Then, based on the results of this study a recommendation for or against the adoption of SNTI by the U.S. Navy will be made.

II. U.S. NAVY SURFACE COMBATANTS

A. CLASSES AND THEIR CAPABILITIES

As stated in the previous chapter, the primary emphasis of this thesis in evaluating ISCS is being given to FFG-7 and DDG-51 class ships. However, it is important to note that most of the capabilities desired in an ISCS for these two classes of ships are remarkably similar to the capabilities required on all U.S. Navy surface combatants. Any differences would be due to specific weapon or detection systems that are unique to that individual class or ship. Such differences would more than likely result in hardware or installation changes rather than changes in the desired requirements of an ISCS.

So, before getting into the specifics of FFG-7 and DDG-51 platforms it would be beneficial to come to an understanding of the differences in design and capabilities of other classes of surface combatants. In order to achieve an understanding of the complexities involved in fighting a ship today, this will include a brief review of the weapon and sensor capabilities of some of the Navy's newest classes of ships [Ref. 1]. This will also provide a clearer view of the thread of commonality that holds for ISCS capabilities and requirements for these ships.

The first of the three types of combatant to be looked at is the cruiser or CG. Today's cruisers have developed from the world's first nuclear powered cruiser, the Long Beach, and her steam powered sister ships of the Leahy class, the first class to be designed as cruisers. The newer classes, using the same basic layout, have developed via the California class to the Virginia class. These two classes are very similar in design. Therefore only a description of the Virginia class will be provided.

For weapons this class has two quad surface-to-surface missile (SSM) launchers, two twin surface-to-air (SAM)/ASW launchers, two five inch guns, two close-in weapons systems (CIWS) and torpedo tubes. It has one missile control director, one ASW FCS and one missile fire control system (MFCS). Its sensors include a 3-D search radar, surface search and air search radars, three FC radars, one navigation radar, a sonar and an EW system. Her basic communications suite includes satellite communication antennas, one SSR-1 receiver and 4 WSC-3 transceivers.

The follow-on to the Virginia was the Ticonderoga class cruiser, the first to be fitted with the Aegis system. The Aegis system provides new levels of anti-air defense of a carrier battle group (CVBG) using the most advanced technology. This system has an electronic scanning radar with a fixed antenna which is capable of aiding in controlling aircraft as well as with surveillance, detection and tracking. It can process its information almost instantaneously to identify friend from foe, assess each threat and via the Navy Tactical Data System (NTDS) control and allocate the fire power of the CVBG's defenses, including friendly aircraft.

The armament for this class is composed of two quad SSM launchers, two twin SAM/ASW launchers (newer ships in the class have two vertical launch systems, VLS, instead), two five inch guns, two CIWS and torpedo tubes. It has the Aegis weapon control system, one gun fire control system (GFCS), four missile guidance illuminators and one ASW FCS. This class has the SPY-1 phased array, 3-D radar for its Aegis system, air search and surface search radars, a weapons FC radar, a navigational radar, a sonar and an EW system. For communications it has satellite communication antennas, four SSR-1 receivers, two WSC-3 transceivers plus the Aegis - NTDS interface capability.

The next type of combatant to be examined will be the destroyer, both the DD and DDG. Starting with the former, we will look briefly at the Spruance class. This class is outfitted with an eight tube SAM launcher plus two quad SSM launchers. The entire class is to be retro-fitted with VLS for the Tomahawk missile. Other weapons include two five inch guns, two CIWS, torpedo tubes and an anti-submarine rocket (ASROC) launcher. For fire control there is one MFCS, one ASW FCS and one GFCS with two associated fire control radars. It also has a 3-D search radar, a surface search radar, a sonar, a towed array and an EW system. The basic communications suite includes satellite communication antennas, an SSR-1 receiver and three WSC-3 transceivers.

The DDG to be looked at is the Arleigh Burke class, DDG-51, and this will be examined in more detail later in this chapter.

The final group to be covered are the frigates, both FF and FFG. The Bronstein class, the first of this type of surface combatant, introduced the slim, high freeboard hull and the ASROC stand-off missile. This missile was matched in range by a large hull mounted sonar; a successful combination. This ASW potency was improved upon with the Garcia class by providing her with organic helicopter assets. Also, half the class was provided with an area defense SAM system. At the time the largest class of frigates, the Knox class, was also dedicated to an ASW escort role. This changed with the development of the Oliver Hazard Perry class, FFG-7. This class, like DDG-51, will be looked at later in the chapter.

B. THE ROLE OF SURFACE COMBATANTS

The role of the U.S. Naval surface combatant is to prosecute enemy forces and/or protect what the U.S. Navy refers to as a high value unit (HVU). This HVU could range from a troop transport to a supply ship to a battleship to the

heart of the U.S. fleet, the aircraft carrier. With the possible exception of the heavily armed battleship, these HVUs rely on surface combatants, or escort ships as they are often called, for firepower and protection. For example, a CVBG will often have a carrier in the center of the force with an inner ring of four cruisers and an outer ring of eight to ten destroyers and frigates. The former is geared primarily for AAW and the latter to a mix of AAW and ASW. The positions ships are assigned in a CVBG is usually based on their missile capability (range) and ASW capability (sonar range).

Next, a brief description of a warfare scenario is offered to provide some groundwork for a better understanding of the myriad of communication requirements demanded today. Even before hostilities are initiated, enormous amounts of intelligence data on force disposition, the threat situation, etc. is available and needs to be disseminated. This information needs to get out not only to the ships in the task force (TF), but internally as well between vital operational stations and key personnel on board ship.

When hostilities do erupt, the U.S. Navy employs the concept of defense-in-depth [Ref. 2]. It works as follows. Airborne early warning (AEW) aircraft from the carrier detect enemy aircraft and by directing combat air patrol (CAP), the AEW enable the CAP to intercept the enemy air strike at extreme ranges before the enemy aircraft can launch their stand-off weapons. Similarly, the airborne radar detects enemy surface forces before they can move against the TF, leaving them vulnerable to counter-attack by long range air-to-surface missiles (ASM) and SSMs. Widely spread enemy air strikes may be beyond the capacity of the CAP and will come into the scope of Aegis platforms. Medium and long range SAMs will be employed first by the outer

screen. Surviving attackers, either aircraft or missiles, which cross the TF's outer boundaries are then challenged by the outer ring's point defense systems and at the same time are coming into range of the inner circle's SAM systems. Point defense systems, which effectively handle crossing targets, then come into play from the inner ring against any hostile aircraft or missiles having penetrated this far. A last ditch defense is provided by the CIWS.

Other defenses, such as the use of EW to provide communication, detection and tracking difficulties for enemy forces, are incorporated into this defense-in-depth concept. Also, each CVBG has at least one friendly submarine assigned to counter enemy submarines and their missile capability.

With the realization that such a scenario could occur within a span of two or three minutes, the stress placed on shipboard communications is enormous. The impact on an ISCS becomes even more apparent when one considers the need for the numerous weapon and sensor stations aboard each ship to be able to interface quickly and efficiently. This is in addition to the information and data exchange between the various warfare commanders and the ships and aircraft in the task force. Therefore, the ability of an ISCS to respond rapidly and accurately is obviously a critical factor in determining the potential survivability of the task force.

C. THE ARLEIGH BURKE CLASS, DDG-51

This section contains descriptions of the DDG-51 outfitting, mission, combat system and personnel who participate in the command and control (C^2) of shipboard operations. The descriptions are intended to aid the reader who is unfamiliar with this class in understanding the communication requirements described in the following chapters. See [Ref. 3].

The DDG-51 class ship is a guided missile destroyer designed to operate as a component of a surface action group

(SAG) or a CVBG, providing defensive protection against air, missile, surface and subsurface hostile forces. These ships emphasize AAW capabilities and as such, will work well in supporting Aegis cruisers, (CG-47), in the air and missile defense of the SAG and CVBG. The DDG-51 can also operate extremely well as an independent unit or in coordination with other ships. As mentioned, her primary emphasis is on AAW with secondary emphasis placed on anti-surface warfare (ASUW), ASW and strike warfare (STW).

This ship's immense capability lies with her Aegis system which employs an electronic scanning radar with fixed antenna. All four SPY-1 radar "faces" are located on the single forward deck house. Control of the Aegis combat system is distributed. It originates with command and is distributed to the various coordinators in response to the threat environment. The warfare coordinators control and direct engagements within their respective areas. As the threat changes the flexibility of the Aegis combat system comes into play. It can be quickly configured to respond to changes in the threat environment, both within and between the various warfare areas. It can respond in seconds to threats that develop with little or no warning.

This combat system is comprised of sensor, weapon, control and support elements. Major system elements are the AN/SPY-1 radar system, the command and decision complex and the weapons control system. Other weapon, sensor, coordination and control elements interact with the weapon control system to form the remainder of the Aegis combat system. More specifically, her armament consists of two VLS/VLA for Tomahawk and ASROC missiles, two quad SSM launchers, one five inch gun, two CIWS and torpedo tubes. For fire control there is one GFCS, one ASW FCS and one MFCS with three associated FC radars. In addition to the SPY-1 multi-purpose phased array radar, there is one surface search radar, a

sonar, a towed array and an EW system. It is also capable of performing on all three of the U.S. Navy's tactical data links; links 4, 11 and 16. The standard DDG-51 communications suite is made up of satellite communication antennas, SSR-1 receivers and WSC-3 transceivers.

1. Warfare Areas and Command and Control Spaces

The combat system can be divided into four areas: anti-air, anti-submarine, anti-surface and strike. Following is a brief description of these areas.

Anti-Air Warfare (AAW). The combat system provides an all-weather AAW capability that includes standard missiles, CIWS, control of carrier based aircraft and the use of EW.

Anti-Surface Warfare (ASUW). Surface warfare can be conducted with guns and anti-surface missiles, either independently or in coordination with a surface action group.

Anti-Submarine Warfare (ASW). These operations can be conducted independently or as part of a coordinated ASW search and attack unit (SAU). The system provides for positive control of ASW aircraft and weapons.

Strike Warfare (STW). The combat system provides the capability to conduct pre-assigned strike warfare either independently or in conjunction with other forces.

Command and control spaces are comprised of the Combat Information Center (CIC), the sonar control area and the pilot house and its ancillary spaces. Following is a description of these spaces and the personnel who man them during Readiness Condition I. This is to provide an understanding of the number of personnel involved in fighting a ship and the potential for communication difficulties to arise.

Combat Information Center (CIC). CIC can be functionally divided into six primary areas: command, tactical information, AAW, ASUW, ASW and STW. Figure 2.1 shows the DDG-51 CIC area.

Command Area. It provides command, i.e., the Commanding Officer (CO) and the Tactical Action Officer (TAO), with the necessary facilities to monitor the tactical situation and make decisions.

Tactical Information Area. It contains displays and facilities for sensor and surveillance system management for air targets and EW and provides the capability for detection, identification and tracking of targets.

AAW Area. It provides displays and facilities for coordinating and controlling engagements with air targets by ship's missiles, guns and CIWS as well as for the close control of aircraft.

ASW Area. It provides displays and facilities for tracking sub-surface targets, coordinating and controlling target engagements and the close control of ASW aircraft.

ASUW Area. It provides displays and facilities for surface tracking, coordinating and controlling engagements with missiles and guns (including over-the- horizon, OTH, and strike warfare), controlling shore bombardment when firing by navigational plot and radar navigation.

STW Area. The STW area is a specialized subarea of ASUW. It becomes a separate warfare area when conducting missile launchings against land targets. At that time it provides displays and facilities for preparation and control of Tomahawk land attack missiles (TLAMS).

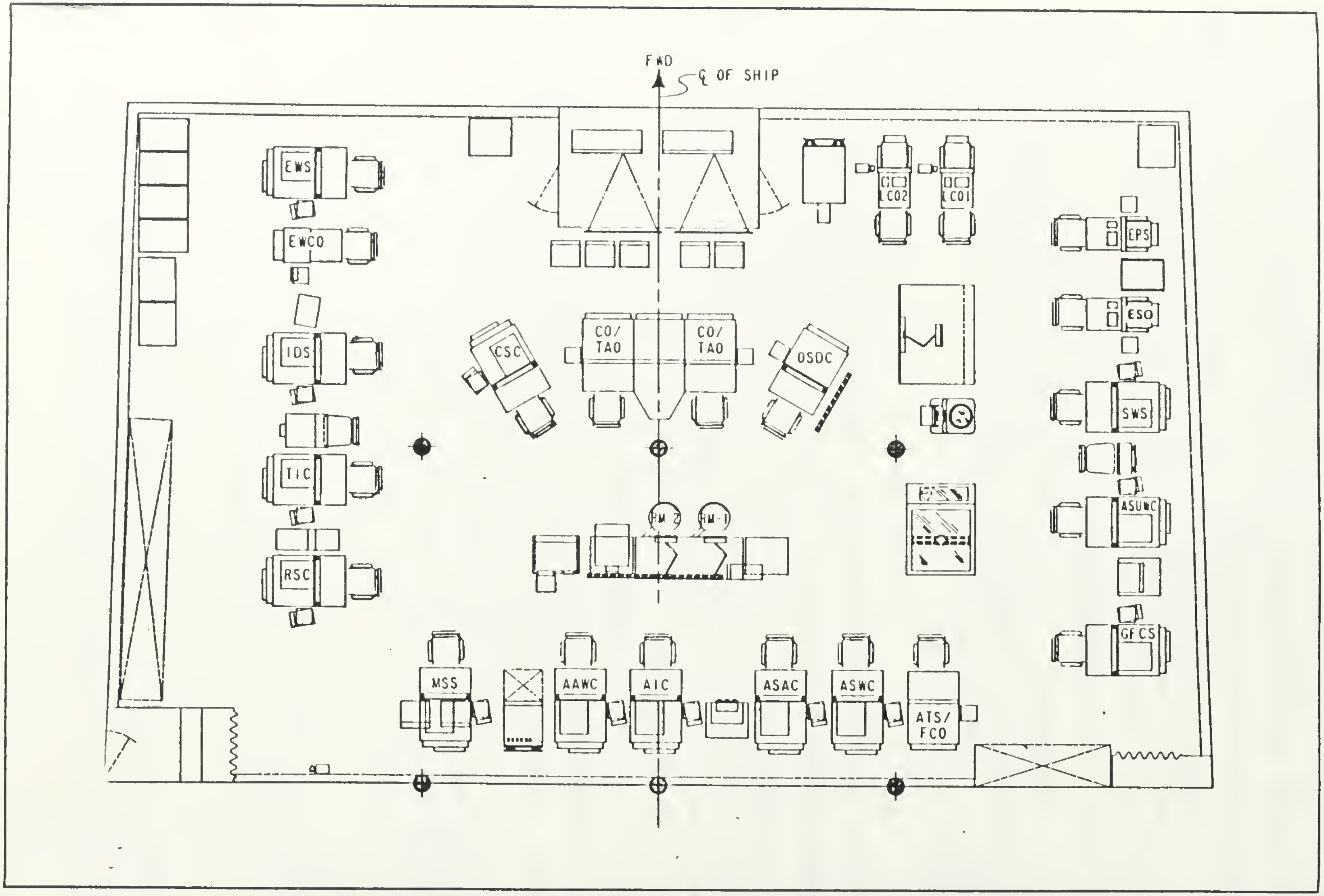

Figure 2.1 CIC on DDG-51 Class Ships.

In addition to the personnel in each of the warfare areas, CIC is also manned by two radio monitors (RM-1 and RM-2), the CIC Supervisor, a damage control phone talker and a Captain's battle talker. These personnel are located immediately behind the command area.

Sonar Control Area. This area is located in a separate space. It provides active and passive sonar surveillance in support of ASW and ASUW operations.

Pilot House and Ancillary Spaces. These areas provide facilities for conning, maneuvering and navigating the ship. They can be divided into four areas: C^2, navigation and piloting, quartermaster and visual communications.

The C^2 area provides facilities for the Commanding Officer, the Officer-of-the-Deck and other personnel who support the CO and OOD in accomplishing ship control operations. Included in these facilities is a console for maintaining a surface detection and tracking function, normally a responsibility of CIC. The console is operated by the Surface Radar Controller (SRC). Command also exercises control over the signal shelter and directs visual communications transmitted and received by the signalmen.

2. Personnel Duties and Responsibilities

This section describes the duties and responsibilities of the personnel who participate in command and control operations during Readiness Condition I. Table 1 shows the manning requirements for CIC, sonar control and the pilot house [Ref. 3].

Readiness Condition I, or General Quarters as it is better known, requires a fully manned C^3 organization along with a fully functioning combat system and weapon system. This condition places the greatest demand on an ISCS and therefore provides us with a worst case scenario. Table 1 is provided to give the reader a better grasp of the number of people and the complexities involved in fighting a ship.

TABLE 1

MANNING REQUIREMENTS FOR READINESS CONDITION I

<u>Combat Information Center</u>

Commanding Officer (CO)
Tactical Action Officer (TAO)
Combat System Coordinator (CSC)
Ownship Display Controller (OSDC)
CIC Supervisor
Radio Monitors
Talker - Captain's battle net
Talker - Damage control net

Tactical Information Coordinator (TIC)
Radar System Controller (RSC)
Identification Supervisor (IDS)
Electronic Warfare Supervisor (EWS)
Electronic Warfare Console Operator (EWCO)

Anti-Air Warfare Coordinator (AAWC)
Missile System Supervisor (MSS)
Air Intercept Controller (AIC)

Anti-Surface Warfare Coordinator (ASUWC)
Surface Warfare Supervisor (SWS)
Extended Surveillance Operator (ESO)
Gunfire Control Supervisor (GFCS)
Engagement Planning Supervisor (EPS)
Launch Control Operators (LCOs)
Plotters

Anti-Submarine Warfare Coordinator (ASWC)
Anti-Submarine Aircraft Controller (ASAC)
Acoustic Track Supervisor/Underwater FC
Operator (ATS/FCO)

<u>Sonar Control Area</u>

Acoustic Supervisor (AS)
Hull Sonar System Operators (HSSOs)
Towed Sonar System Operator (TSSO)
Acoustic Sensor Operator (ASO)

<u>Pilot House</u>

Officer of the Deck (OOD)
Conning Officer
Navigator
Navigator's Assistant
Quartermaster-of-the-Watch (QMOW)
Boatswain's Mate-of-the-Watch (BMOW)
Ship Control Console Operator
Ship Control Console Operator; standby
Messenger
Talker - Captain's battle net
Talker - Damage control net
Surface Radar Controller (SRC)
Lookouts

Commanding Officer. The CO is responsible for overall command of the ship. He also acts as strike warfare coordinator.

Tactical Action Officer. The TAO is the principal command decision maker under the direction of the CO. Authority is delegated to the TAO for control of the Combat System in all matters relating to tactical employment and defense. If the TAO console fails he will monitor the CO or OSDC console or relocate with the AAWC. In all cases of console failure the relocation to another console is dictated by the present tactical situation.

Combat System Coordinator. The CSC is responsible for controlling the configuration of the combat system. He monitors system status and operation and allocates system resources to the warfare coordinators. If the CSC console fails, he will relocate to the alternate Radar System Controller (RSC) console in the Combat System Equipment Room (CSER).

Ownship Display Controller. The OSDC is responsible for maintaining the command displays, specifically the large screen display (LSD), Aegis display system (ADS) and the automatic status boards.

CIC Supervisor. The CIC supervisor positions himself in proximity to the TAO, but is free to supervise where needed or to substitute at any console operator's position. He acts as the primary enlisted assistant to the TAO and as the tactical communicator.

Radio Monitors. The two radio monitors are located at the communication table in the command area. They are responsible for transmitting, receiving and logging exterior communications.

Talkers. Two S/P phone talkers are located in the command area to monitor the Captain's battle net and Damage control net.

Tactical Information Coordinator. The TIC is responsible for ensuring that the information displays of the tactical data base are accurate and sufficient to support the warfare coordinators in performing their tasks. If the TIC console fails, he will relocate to the EWS console in CIC or to the alternate RSC console in the CSER.

Radar System Controller. The RSC, under direction of the TIC, is responsible for operation and performance of the SPY-1 radar. If the RSC console fails, he relocates to the alternate console in the CSER.

Identification Supervisor. The IDS is responsible for establishing the identity, category and classification of assigned surveillance targets. If the IDS console fails, he would relocate to the EWS console.

Electronic Warfare Supervisor. The EWS is responsible for monitoring and controlling electronic support measures. If the EWS console fails, he coordinates data entry with the TIC via interior communications.

Electronic Warfare Console Operator. The EWCO reports EW information and target correlation data to the EWS. He is responsible for the configuration, control and monitoring of the EW system.

AAW Coordinator. The AAWC is responsible for coordination and direction of all own-ship AAW assets, including assigned aircraft. If his console fails, he relocates to the CO console or to the alternate AAWC console in the CSER.

Missile System Supervisor. The MSS initializes and controls the FCS and VLS for engagement of assigned air targets and for the launch of ASROC when assigned. If the MSS console fails, he will relocate to the AAWC console and the AAWC will relocate to his alternate console in the CSER.

Air Intercept Controller. The AIC is responsible for controlling assigned aircraft. If his console fails, he relocates to either the ASAC or alternate AAWC console.

ASUW Coordinator. The ASUWC is responsible for the coordination and direction of all own-ship anti-surface assets, including assigned aircraft. If the ASUW console fails, he relocates to the SWS or to the CO console.

Surface Warfare Supervisor. The SWS, under the direction of the ASUWC, controls surface warfare sensors, evaluates the surface situation and monitors weapon engagements. If the SWS console fails, he relocates to the alternate AAWC console in the CSER.

Extended Surveillance Operator. The ESO is responsible for maintaining extended surveillance (OTH) data. If the ESO console fails, he relocates to the LCO console or to the alternate LCO console in the CSER.

Gunfire Control Supervisor. The GFCS is responsible for the performance of the gun weapon system. If his console fails, he can relocate to any other CIC console.

Engagement Planning Supervisor. The EPS is responsible for planning Tomahawk anti-ship missile (TASM) and land attack missile (TLAM) engagements for ASUW and STW operations. If the EPS console fails, he relocates to the LCO or ESO console in CIC or to the LCO alternate console in the CSER.

Launch Control Operators. Two LCOs, under the direction of the EPS, are responsible for launching Tomahawk missiles. If an LCO console fails, they can shift to the other LCO console in CIC or to the alternate LCO in the CSER.

Plotters. The plotters are responsible for operating the Digital Dead Reckoning Tracer (DDRT) and maintaining a surface and subsurface plot. There is only one DDRT.

ASW Coordinator. The ASWC is responsible for the coordination and direction of all own-ship ASW assets, including assigned aircraft. If the ASWC console fails, he relocates to the SWS console.

Anti-Submarine Aircraft Controller. The ASAC is responsible for controlling assigned ASW aircraft. If the ASAC console fails, he relocates to the ATS/FCO console or to the alternate RCS console in the CSER.

Acoustic Track Supervisor/Underwater Fire Control Operator. The ATS/FCO is responsible for subsurface tracks and controls all ASW weapons with the exception of aircraft. If his console fails, he relocates to the acoustic supervisor's console in sonar control.

Acoustic Supervisor. The AS, under the direction of the ASWC, is responsible for the supervision of the sonar control area. If the AS console fails, he will relocate to an alternate console in the sonar control area.

Sonar Operators. The sonar operators are comprised of two HSSOs, the TSSO and the ASO. They are responsible for operation of the sonar systems and the detection and classification of underwater targets. In the event of console failure, they relocate to other console positions in sonar control.

Officer-of-the-Deck. The OOD, under direction of the TAO (acting for the CO), is responsible for all ship control functions. He has no console per se.

Surface Radar Controller. The SRC, under the supervision of the SWS, is responsible for detection and classification of surface targets, low-flying aircraft and submarine snorkels/periscopes. There is not an alternative console for the SRC.

3. Subscriber Requirements of an ISCS

As mentioned previously, Readiness Condition I places the greatest demand on an ISCS, due primarily to the increase in the number of subscribers (the users of an ISCS - TAO, EWS, AIC, etc.) and their associated communication requirements. The tables in Appendix "A" are provided to assist the reader in grasping the enormous communication

tasking and system coordination that fighting a ship requires. The listings are not intended to provide a comprehensive account of subscriber requirements. They are intended to provide a basis for a general understanding of the scope of subscriber requirements; keeping in mind the tremendous demand this can place on an ISCS.

D. THE OLIVER HAZARD PERRY CLASS, FFG-7

This section will emphasize the other class of ships that will be emphasized, the Oliver Hazard Perry (FFG-7) class. It will provide a review of FFG-7 mission, combat system and personnel who participate in the command and control of shipboard operations.

The FFG-7 class is a guided missile frigate whose general mission is to operate offensively with ASW forces, with SAGs, in the protection of underway replenishment groups, in support of amphibious assaults and to protect military and commercial shipping against attack.

Control of the FFG-7 combat system is distributed. It originates with the Commanding Officer and is distributed through the chain of command. Combat system control, consisting of sensors, display and decision, weapons control and weapons system is directed by command (via the TAO as authorized by the CO) and controlled by the WeaponS Control Officer, ASW Evaluator and EW Supervisor.

The combat system provides the capability to detect, evaluate, acquire, engage and deceive enemy air, surface and subsurface threats. The system is comprised of sensor, control, weapon and support elements. For armament, this class is fitted with one Guided Missile Launching System (GMLS) for both SSMs and SAMs, one 76MM gun and one CIWS. The ship's fire control system consists of one MFCS, one GFCS and two FC radars. It is equipped with two other radars, a 2-D air search radar and a surface search radar. Additional sensors include a hull mounted sonar, a towed

array system and an EW system. The basic communications suite includes satellite communication antennas, one SSR-1 receiver and two WSC-3 transceivers. The remainder of this section provides a description of the C^2 spaces and the personnel who man them on during Readiness Condition I on FFG-7 ships. But, before continuing it's important to note the basic differences and functions between this class and DDG-51.

The Aegis system, particularly the phased array radar, allows DDG-51 to play a more complex, multi-faceted role in a combat scenario. A much larger crew complement also allows for more well defined and specific tasking of personnel. With FFG-7 class, the role the ship plays is much more limited and restricted. In addition, the concept of minimum manning on this class requires a much more general and flexible tasking with respect to personnel.

1. <u>Warfare Areas and Command and Control Spaces</u>

The combat system can be divided into three areas: anti-air, anti-submarine and anti-surface. Following is a brief description of these areas.

<u>Anti-Air Warfare</u> (<u>AAW</u>). The combat system provides an all-weather AAW capability that includes standard missiles, CIWS, control of carrier based aircraft (though not regularly assigned) and the use of EW.

<u>Anti-Surface Warfare</u> (<u>ASUW</u>). Surface warfare can be conducted with guns and anti-surface missiles, either independently or in coordination with a surface action group.

<u>Anti-Submarine Warfare</u>. ASW operations can be conducted independently or as part of a coordinated ASW search and attack unit (SAU). The system provides for positive control of ASW aircraft and weapons that can be launched either over the side or from ASW aircraft.

Command and control spaces are comprised of the Combat Information Center (CIC), the sonar control area and

the pilot house and its ancillary spaces. Following is a description of these spaces and the personnel who man them during Readiness Condition I. This is to provide an understanding of the number of personnel involved in fighting a ship and the potential for communication difficulties to arise.

Combat Information Center (CIC). CIC can be functionally divided into four primary areas: display and decision, detection and tracking, weapons control and ASW. Figure 2.2 shows the FGG-7 CIC area.

Display and Decision Area. It provides command, i.e., the Commanding Officer (CO) and the Tactical Action Officer (TAO), with the necessary facilities to monitor the tactical situation and make decisions.

Detection and Tracking Area. It contains displays and facilities for sensor and surveillance system management of all surface, subsurface and air targets and EW and provides the capability for detection, identification and tracking of targets.

ASW Area. It provides displays and facilities for tracking sub-surface targets, coordinating and controlling target engagements and the close control of ASW aircraft.

Weapons Control Area. It provides displays and facilities for surface and air tracking, coordinating and controlling engagements with missiles, guns and CIWS (including over-the- horizon, OTH, targeting), as well as close control of aircraft, controlling shore bombardment when firing by navigational plot and radar navigation.

In addition to the personnel in each of the warfare areas, CIC is also manned by two radio monitors (RM-1 and RM-2), the CIC Supervisor, a damage control phone talker and a Captain's battle talker. These personnel are located immediately behind the command area.

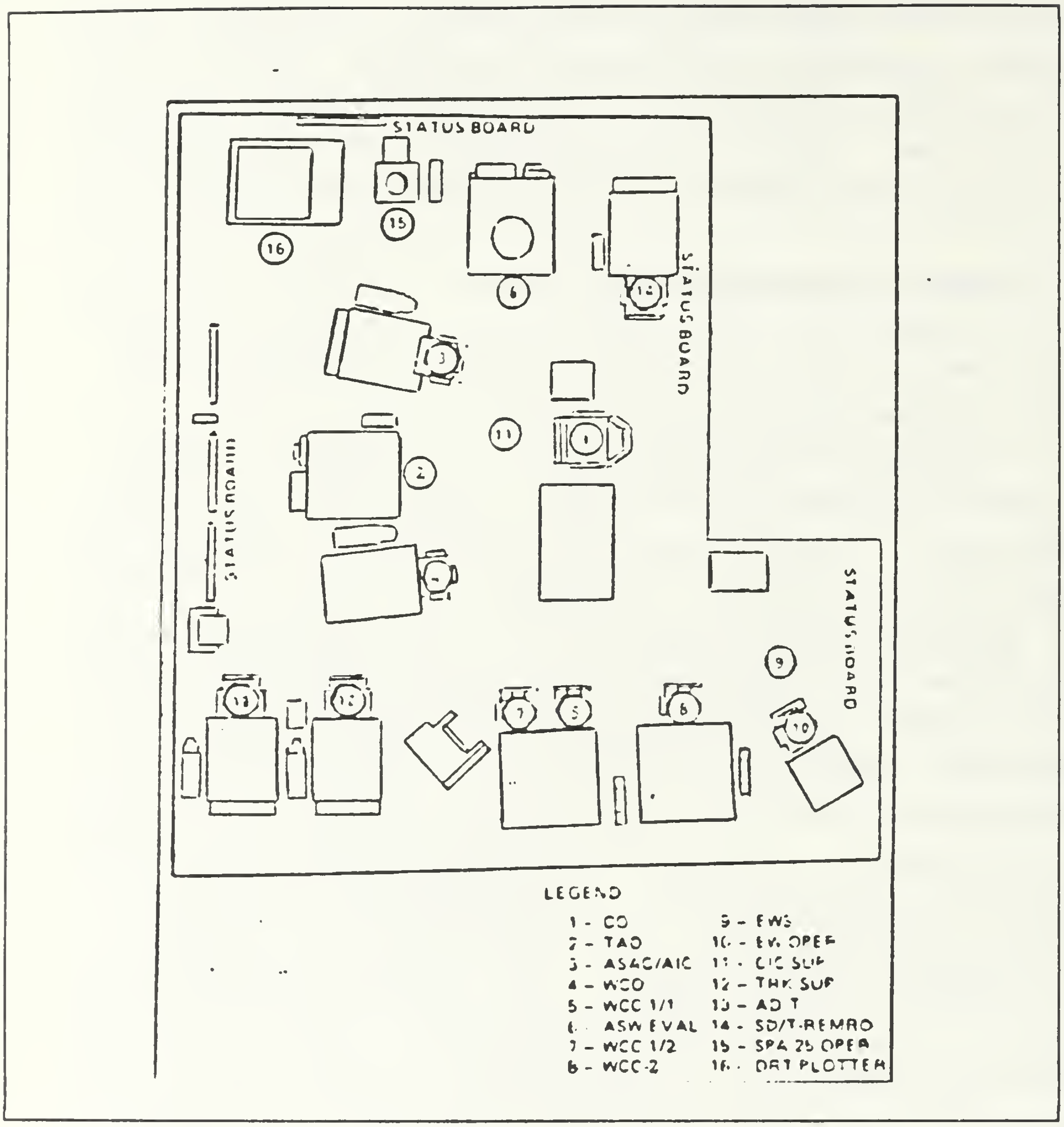

Figure 2.2 CIC on FFG-7 Class Ships.

Sonar Control Area. This area is located in a separate space. It provides active and passive sonar surveillance in support of ASW and ASUW operations.

Pilot House and Ancillary Spaces. These areas provide facilities for conning, maneuvering and navigating the ship. They can be divided into four areas: C^2, navigation and piloting, quartermaster and visual communications.

The C^2 area provides facilities for the Commanding Officer, the Officer-of-the-Deck and other personnel who support the CO and OOD in accomplishing ship control operations. Included in these facilities are two radar repeaters (instead of a Surface Radar Console) for maintaining a surface detection and tracking function, normally a responsibility of CIC. Command also exercises control over the signal shelter and directs visual communications transmitted and received by the signalmen.

2. Personnel Duties and Responsibilities

This section describes the duties and responsibilities of the personnel who participate in command and control operations during Readiness Condition I. Table 2 shows the manning requirements for CIC, sonar control and the pilot house.

Commanding Officer. The CO is responsible for overall command of the ship.

Tactical Action Officer. The TAO is the principal command decision maker under the direction of the CO. Authority is delegated to the TAO for control of the Combat System in all matters relating to tactical employment and defense. He has no warfare coordinators (as does the DDG-51 TAO) to delegate his authority to. If the TAO console fails he will relocate to the ASW Officer Console (ASWOC) and the ASW Eval moves to the DRT. In all cases of console failure the relocation to another console is dictated by the present tactical situation.

CIC Supervisor. The CIC supervisor positions himself in proximity to the TAO, but is free to supervise where needed or to substitute at any console operator's position. He acts as the primary enlisted assistant to the TAO and as the tactical communicator.

Radio Monitors. The two radio monitors are located at the communication table in the command area. They are

TABLE 2

MANNING REQUIREMENTS FOR READINESS CONDITION I

Combat Information Center

Commanding Officer (CO)
Tactical Action Officer (TAO)
CIC Supervisor
Radio Monitors
Talker - Captain's battle net
Talker - Damage control net

Track Supervisor (TRKSUP)
Electronic Warfare Supervisor (EWS)
Electronic Warfare Console Operator (EWCO)
Surface Detector Tracker (S/DT)
Air Detector Tracker (A/DT)
Dead Reckoning Tracer (DRT) Plotters

Weapons Control Officer (WCO)
Weapons Control Console Operator (WCC-1/1)
Weapons Control Console Operator (WCC-1/2)
Weapons Control Console Operator (WCC-2)

Anti-Submarine Warfare Evaluator (ASW Eval)
Anti-Submarine Aircraft Controller (ASAC)

Sonar Control Area

Sonar Supervisor (Sonar Sup)
Stack Operator
Towed Sonar System Operators (CD #1 and CD #2)
Mk 309 Operator

Pilot House

Officer of the Deck (OOD)
Conning Officer
Navigator
Navigator's Assistant
Quartermaster-of-the-Watch (QMOW)
Boatswain's Mate-of-the-Watch (BMOW)
Ship Control Console Operator
Ship Control Console Operator; standby
Messenger
Talker - Captain's battle net
Talker - Damage control net
Spa-25 Radar Repeater Operator
Lookouts

responsible for transmitting, receiving and logging exterior communications.

Talkers. Two S/P phone talkers are located in the command area to monitor the Captain's battle net and Damage control net.

Track Supervisor. The TRKSUP monitors and supervises the detection, entry, classification and tracking operations. If his console should fail, he would move to either the A/DT or S/DT console.

Electronic Warfare Supervisor. The EWS is responsible for monitoring and controlling electronic support measures. If the EWS console fails, he coordinates data entry with the TRKSUP via interior communications.

Electronic Warfare Console Operator. The EWCO reports EW information and target correlation data to the EWS. He is responsible for the configuration, control and monitoring of the EW system. There is only one EW console.

Weapons Control Officer. The WCO, under the direction of the TAO, selects targets for engagements and assigns appropriate FC channels and weapons for acquisition, tracking and FC solutions. In case the WCO console fails. he relocates to the ASAC/AIC console.

Air Intercept Controller. The AIC is responsible for controlling assigned aircraft. If his console fails, he relocates to either the WCO or ASWO consoles.

Air Detector Tracker. The A/DT provides new track entry on all video, enters identity and composition of all tracks within the surveillance area and correlates EW data with radar tracks. If his console should fail, he relocates to either the S/DT or TRKSUP console.

Surface Detector Tracker. The S/DT searches for and initiates new tracks for detected surface and low flying aircraft, updates tracks, enters identification on new tracks an provides track data for radar navigation. In case of console failure, he would move to either the A/DT or TRKSUP console.

Weapons Control Console Operators. The WCC operators are responsible for the efficient use of the guided missile launching system (WCC-1/1 and WCC-2), the Harpoon control panel and the CIWS remote panel (WWC-1/2) and the gun (all three WCCs).

Plotters. The plotters are responsible for operating the Dead Reckoning Tracer (DRT) and maintaining a surface and subsurface plot. There is only one DRT.

ASW Evaluator. The ASW Eval is responsible for the coordination and direction of all own-ship ASW assets, including assigned aircraft. If the ASWOC fails, he relocates to the DRT plot.

Anti-Submarine Aircraft Controller. The ASAC is responsible for controlling assigned ASW aircraft. If the ASAC console fails, he relocates to the WCO console.

Sonar Supervisor. The Sonar Sup, under the direction of the ASW Eval, is responsible for supervision of the sonar control area.

Sonar Operators. The sonar operators are comprised of the Stack Operator, Mk 309 Operator, and the two Towed Sonar System Operators. They are responsible for operation of the sonar systems and the detection and classification of underwater targets. In the event of console failure, they relocate to other console positions in sonar control.

Officer-of-the-Deck. The OOD, under direction of the TAO (acting for the CO), is responsible for all ship control functions. He has no console per se.

Spa-25 Radar Repeater Operator. This operator is responsible for detection and classification of surface targets, low-flying aircraft and submarine snorkels/ periscopes. There is not an SRC console located on the bridge as on the DDG-51 class.

3. Subscriber Requirements on an ISCS

Appendix "B" contains descriptions of the subscriber (user) requirements of individual console operators and C^2 personnel. The listings are not intended to provide a comprehensive account of subscriber requirements. They are intended to provide a basis for a general understanding of the scope of subscriber requirements; keeping in mind the tremendous demand this can place on an ISCS.

The material covered so far (including the tables in the appendix) has been presented to provide the reader with a framework from which to understand the workings of an ISCS. The brief introduction to surface combatants along with descriptions of the part they play in a warfare scenario should help illuminate the important role an ISCS has in contributing to the success a ship has in meeting its mission requirements. The identification of the players (users) in shipboard C^3 along with their communication needs is provided to highlight the heavy demand placed on an IC system as well as the complex operations necessary for such a system to function properly. With this background, the next chapter will show some of the problems inherent in designing a viable ISCS, as well as, the requirements a successful ISCS must meet.

III. INTEGRATED SHIPBOARD COMMUNICATION SYSTEM REQUIREMENTS

This chapter will examine some of the C^3 problems caused by either the absence of an ISCS or the design flaws on installed systems. It will then provide a description of design and system features and capabilities that are desirable in the ISCS of the future. See [Ref. 4] and [Ref. 5].

A. PRESENT SYSTEMS

The source of many of todays C^3 problems are a direct result of unsatisfactory interior communications. Some of the systems and their design features (sound powered telephones for example) date back to WWII with little or no change in operation or capabilities. This, despite the obvious technological advances in all other areas of naval warfare. But before going any further, a brief description of the various types of IC systems will be given.

Sound-Powered (S/P) Telephones. Though somewhat antiquated and not easily adaptable to changing scenarios, S/P phones are still considered to be the most reliable and survivable means of communication aboard ship. This is because they are independent of external electrical power. They require no outside power supply for operation since the sound waves produced by the speaker's voice provide the necessary energy to reproduce the voice at a remote location. A hand cranked magneto generator or an external buzzer provide the audible alert or ringing power.

Multi Channel Circuit (MMC). Shipboard one-way announcing systems serve the general purpose of transmitting orders and information between stations by amplified voice communications. MCCs are a microphone speaker system designed to provide rapid voice communications between two or more stations, During normal cruising, MCCs can be

considered an auxiliary to S/P phone circuits and should only be used when necessary. Indiscriminate use of MCCs lowers its value for emergency communication and raises the noise level above acceptable limits in C^2 spaces.

Intercom Systems. Intercom or interphone systems provide selected communication between selected watch stations. These calls or messages can be transmitted and received over console speakers, handsets or headsets. Normally a channel or station selection switch must be invoked to establish communications. Due to its simplicity of operation and ease of access to different watch stations this is the preferred method of communication between watch stations.

Ship Service Telephone System. This system is very similar in principle to a home phone system. That is, to the user the basic function is the same - selectable calling of another telephone terminal. The selection of a station can be via dial-up, selectable switch or push button. An audible signal is provided at the called terminal to notify the user at that station.

Radio Telephone (R/T) System. This is the system used to provide external communication between a user aboard ship and a user at a location external to the ship. Communication is via a handset or a headset and can be either secure or non-secure in nature.

During normal operations or peacetime cruising the performance of each of these systems is satisfactory. However, with an increase in the operating tempo comes a corresponding increase in the demand placed on these systems with an alarming drop in their performance level. The decrease in the ability of these communication systems to meet the ever increasing demand placed on them by a technologically advancing navy can be traced to the general problem or deficiency areas found in Table 3 [Ref. 6: p. 1].

TABLE 3
SHORTCOMINGS OF EXISTING COMMUNICATION SYSTEMS
Non-integrated
Non-survivable
Manpower intensive
Noisy and mutually disruptive
Inflexible
Slow and unreliable
Inadequately interfaced with combat systems

These C^3 system shortcomings are the result of the design of communication systems and the method of exchanging information. The design of the system slows and degrades communication exchange because the systems currently used to control and coordinate operations are inappropriately designed for that purpose. The method for exchanging information has always been via voice communications. As information exchange requirements have increased, more voice communication systems have been added to meet the demand. This has resulted in a proliferation of independent IC systems that hinders rather than helps effective communication flow. In addition to the confusion caused by the expanding number of IC systems and the hardware that accompanies them, there is also a corresponding increase in the number of personnel required to assist in maintaining a satisfactory flow of traffic. These additional personnel have increased the complexity of the communication problem and, in many cases, are just another obstacle to work around.

In most instances the five communication systems just discussed are independent of each other, resulting in a

ship's interior communication system that has the following characteristics [Ref. 4]:

1. Individual systems using different technologies requiring specialized training of maintenance personnel in many different types of equipment.
2. Systems are hardwired with no provisions for adding or deleting stations or reconfiguration in the event of battle damage to a portion of the ship.
3. Vulnerability of electrically powered systems to interruption of the normal power supply, i.e., no provision for uninterrupted power supply (UPS).
4. Reliance on telephone talker personnel to accurately relay information between watch station decision makers, which reduces the speed of information transfer and has significant potential for error introduction.
5. Increased watch station personnel requirements.
6. Inadequate interfaces with combat systems and no integration with external communication systems.
7. Watch stations that are physically cluttered with an assortment of radio and S/P phone handsets, internal and external communications loudspeakers, microphones, two-way internal communication terminals, status boards and ship's telephones. This requires key personnel to be knowledgeable in the operating characteristics of each system, determine which systems to use for communications with specific watch stations and repeat information as necessary to relay personnel, all of which results in distractions for the decision maker.
8. Restricted access and movement on/to watch stations due to space requirements of systems.
9. Excessive noise at the watch stations with potential for missed information due to simultaneous transmission.

B. SYSTEM/DESIGN CONSIDERATIONS.

An obvious way to eliminate many of the faults given in the prior section is to combine the different systems into one IC system. The U.S. Navy has begun to do this with what is frequently called the Integrated Shipboard Communication System (ISCS) and is also referred to as a multi-capability voice communication system. There are numerous advantages to such a system. An ISCS offers the opportunity to:

1. Combine traditional voice IC functions.
2. Improve information transfer capacity.
3. Reduce shipboard maintenance action.

4. Reduce the clutter of communication system terminals at watch stations.

5. Substitute digital data display for much of the status information that is currently transferred by voice communications.

Current efforts seek to improve operation of different IC systems through the application of today's technology which is aimed at increased speed, reliability, intelligibility, simplified terminal operation and efficiency of maintenance actions. Introduction of the Integrated Voice Communication System (IVCS) in both the LHA class and the CG-47 class ships has provided the first serious attempt at elimination of overlapping IC functions by providing multi-capability systems [Ref. 4: p.2-3]. These systems have the following characteristics:

1. Fewer total terminals resulting in reduced overall cabling requirements.

2. Improved intelligibility and voice quality.

3. Access to radio, one-way announcing systems, S/P phones, and ship's service telephone from the same terminal.

4. Four digit pushbutton dialing, with single button abbreviated addressing for frequently called subscribers and nets.

5. Dial-up and command net conferencing.

6. Alternate power source in the event of a loss of primary electrical power.

7. Reduction in range of maintenance training requirements due to reduce numbers of different equipment and commonality of terminals throughout the ship.

8. Addition/deletion of terminals through the use of modular equipment and software changes.

1. Console Design

No discussion of ISCS requirements can be considered complete with out some mention of console (terminal) requirements. While any attempt at presenting in-depth console design requirements and hardware specifications is beyond the scope of this thesis, a brief summation linking console specifications to a few of the major fundamental requirements of a successful IC system will be provided.

In order to meet the ISCS requirements there are some general desired features that should be incorporated into console design. These communication attributes are given from the point of view of the console operator who must interface directly with the hardware devices. These characteristics, found in [Ref. 7: p. 2-5] are:

1. Multiple communications media access must be by a single communications terminal due to limited operator freedom of movement.

2. Manual control actions must be minimized to prevent interference with console manual interface and facilitate operator concentration on visual information displays.

3. The changing tactical situation may require the operator to instantaneously shift to alternate circuits without disrupting control actions associated with the ongoing action.

4. Incoming call and console alerts must be distinctive and gain operator attention without becoming an annoyance if the operator is otherwise engaged in higher priority tasks.

5. Urgent IC calls must have non-blocking access to the operator, but must have lower priority than external communications in progress.

6. Interconsole net communication capability should allow preselection of net participants to fit the tactical situation.

7. Secure and non-secure communications should be available at key console stations.

8. Emergency (S/P) IC should be instantaneously available in the event of total system failure.

The major fundamental requirements of an ISCS that should be incorporated into console design are speed and simplicity of operation, integration and flexibility (these will be discussed in more detail later). Speed and simplicity can be satisfied by consolidating all IC subscribers at a single terminal location. This allows for easier access to the various circuits that an operator may need to communicate with other subscribers. Labelling of buttons and switches by title would eliminate the need for an operator to memorize numbers or to activate a number of controls to initiate a call and thus help simplify and speed up communications.

Integration can be met by incorporating the various IC systems into one terminal. This provides the user with quick and easy access to the type of transmission medium needed in performing his assigned tasks.

Finally, the requirement for flexibility can be satisfied by allowing pre-programming of the terminals, enabling them to be configured for the specific communication requirements of individual operators and easily reconfigured when changes occur in their communication needs. This also allows operators the flexibility to switch consoles in case of a malfunction or failure to their primary console.

2. <u>Human Factor Considerations</u>

Another important area that cannot be overlooked is that of human factor considerations and along with them the concepts of form, fit and function. The pressures placed on an operator during high tempo operations, plus the potential for long periods of time on watch at a console without relief, demand that the operator be able to maintain his highest performance level, both physically and mentally. Human factor considerations play a major role in assisting operator performance. The following paragraphs, taken from [Ref. 8: p. 3-1] emphasize the importance of this point.

Console operators have severe demands placed on sensory capacity, vigilance, perception and decision making ability in relation to display indications. The primary sense used by the operator is visual perception, which provides for target detection, symbol recognition, alphanumeric readout and indicators linked to the execution of a control action. During periods of low operational activity, such as peacetime transit in open ocean areas, the operator's visual sense is used only moderately and console control actions are few. During these times, operation of the separate system element controls do not tax the operator

and there is little distraction due to other activity in the immediate vicinity. However, as the tempo of operations increases, the operator's visual and aural senses become quickly overloaded and mental stress increases to an extremely high level. At this point, any incompatibility of system components will become apparent through increased operator errors or inability to execute control actions fast enough to effectively support the C^2 node (e.g., continuity of command, maintaining the common tactical picture). To solve this problem, it would seem that each of the system elements should be separately re-evaluated to optimize its capability and permit easier operation. However, care must be taken in this approach to ensure that the improved system element (or subsystem of the overall system) is able to work in harmony with the total system. In the specific case of a console mounted terminal, it would seem that optimum design should, therefore, consider the following:

1. Minimize visual reference requirements in order to maintain operator concentration on tactical displays.
2. Eliminate error provocative features (such as multi-function buttons or lengthy button sequences) to reduce the chance of operator error during high tempo operations.
3. Decrease the amount of effort required by considering economy of motion and compatibility of psychomotor skills with other console subsystems.
4. Choose the proper control devices that contribute to speed and accuracy of operator movements.
5. Consider the overall ensemble of displays and control devices to ensure that information presentation is consistent with other displays, so the operator can easily and correctly identify a particular system output when needed.

Cutaneous sensitivity follows vision and auditory sensitivity in relative importance to a console operator. Touch is particularly good for spatial orientation if controls are simple to use, require minimum visual reference and are within the physical reach limits of the operator. This would seem to indicate that the communication front panel should be primarily a touch-oriented system, with a

minimum number of controls/indicators. However, the obvious use of multi-function controls to achieve an uncluttered front panel also requires increased visual reference, which reduces the importance of spatial orientation by touch. The basic design questions to be addressed then are: 1) What is the proper allocation of operator sensory channels?; and 2) What are the proper controls/indicators to use with each sensory channel?

Communication terminal placement is critical to operator effectiveness. While terminal locations supporting non-console C^2 personnel are generally less sensitive to size and exact placement of installation, the physical space limitations and restrictions available in a console impose design constraints that may limit hardware options. The most restrictive dimensions are those of the front panel. Since only a finite number of switches/indicators of useable size can fit into this area, a trade-off between capability versus human factors results early-on in system design. The following are some of the placement factors that must be analyzed to permit the most effective integration of the communication terminal with the combat systems console.

1. What is the operator's radius of movement?
2. What non-communication control functions are already allocated to the right and left hands?
3. What is the effective viewing distance of various size labels and indicators?
4. What are the environmental conditions (noise, heat, illumination, etc.) at the watch station?
5. What is the character of the operator population (skill level, training, span of concentration, speed of perception, visual acuity, general intelligence)?

With these factors now taken into consideration, we will move on to the following section. This next section will expand upon the fundamental requirements presented earlier, in addition to identifying more specific operational capabilities needed to meet the growing demand placed on today's ISCS.

C. DESIRED FUNCTIONS AND CAPABILITIES

Rapid, accurate, reliable and survivable voice communication between shipboard watch stations is a basic, though vital, requirement for mission success. In order to eliminate some of the IC problems alluded to earlier as well as help maximize ship effectiveness to the battle group an ISCS must meet certain minimum required standards. A list of these standards are shown in Table 4 and their definitions are given below.

TABLE 4

DESIRED FUNCTIONS AND CAPABILITIES

Speed and Simplicity
Integration
Flexibility
Standardization
Communication Configuration Capability
System Reconfiguration
Survivability
- Anti-jam Protection
- Low Probability of Intercept (LPI)
- Invulnerability to "Cheap Kill"

Protection from Radiation Hazards (RADHAZ)
Emergency Power
Maintenance
Environmental Considerations
Secure Voice
Privacy
Monitoring Capability

Single Instrument Access and Selection
Single Action Calling
Busy Circuit Indication
Incoming Call Alert
Identity (ID) of Calling Party
Identify Urgency of the Call
Call Override
Break-In
Call Hold
Hunt-Not-Busy
Conference Call
Instrument Design
Single Action Transmission
Brightness Control
Volume Control

The first portion of the list consists of fundamental requirements that should form the framework for the design of an ideal ISCS. The second half of the list contains a more definitive listing of required operational capabilities that an ISCS should incorporate in order to satisfy the fundamental design requirements.

Speed and Simplicity. The system must provide for fast operation and response with a minimum number of control actions required to operate individual communication terminals. This helps speed information and data exchange and assists in maintaining operator concentration on tactical displays. Therefore, complexity of operation, even if it results in useful system features, is undesirable if it compromises the fundamental requirement of speed and simplicity of operation [Ref. 3: p. 20].

Integration. Communication terminals must have the capability to integrate all of the communication media required by a console operator. This will help eliminate the proliferation of terminals, handsets, microphones, etc., that is presently slowing and degrading shipboard communications.

Flexibility. The system must provide flexibility to enable it to be configured for the communication requirements of each class of surface combatant. It is also required in terminal design to enable the terminals of individual users to be configured to their specific needs. The system must also be flexible enough to ensure that shipboard personnel are capable of making rapid changes in communication configurations when changes occur in requirements.

Standardization. Maximum standardization of hardware components and ship communication architecture is desired to minimize and simplify the number of interfaces and their costs. Commonality with current telecommunication commercial technology to reduce development, acquisition and life dycle support costs is a desirable goal [Ref. 7: p. 2-2].

Communication Configuration Capability. This capability is required to configure console communications for the specific exterior and interior communication needs of each user and to quickly reconfigure communications in the event that an operator must change console positions because of console failure or malfunction. This is analogous to the flexibility requirement but on a smaller scale.

System Reconfiguration. This is the capability to add or delete stations from the system in order to support changing C^2 requirements. Further, system configuration and hardware components/circuit accesses must be such that changes in system configuration can by made by shipboard personnel in a timely manner and without the need for outside assistance.

Survivability. This capability provides communication to surviving system hardware components within the surviving sections of the ship (after battle damage) with minimum reconfiguration actions. An ability to display the surviving capabilities of a terminal to its user is also required. Anti-jam protection, LPI and invulnerability to "cheap kill" are part of this.

Anti-jam Protection. The system must not be vulnerable to hostile EW or degradation due to own ships Electromagnetic Interference (EMI).

Low Probability of Intercept (LPI). The system must not radiate detectable signals external to the ship. Plus, when interfaced with an external communication system (an R/T net), the system must not transmit a unique identifying signature.

Vulnerability to "Cheap Kill." The system must ensure that vital stations will not lose communications due to "cheap kill" hits such as weapon air bursts within 100 feet of the ship, small arms fire, etc.

Protection from Radiation Hazards (RADHAZ). This capability is required to protect the ship from (nuclear) radiation hazards and Electromagnetic Pulse (EMP). In addition to preventing system degradations, exposed terminals must be easily decontaminated to protect personnel during continued system use after a nuclear attack.

Emergency Power. An emergency source of electrical power is required to enable personnel to communicate when a ship's primary source of electrical power fails or malfunctions.

Maintenance. The capability is required to provide automatic system performance monitoring of hardware components and circuit connectivities of IC circuits communication system termination paths. Additionally, visual readout of hardware component casualties should be provided down to the lowest replaceable unit level to assist rapid corrective maintenance action.

Environmental Considerations. The components of the system must be capable of operating in environments containing potentially explosive mixtures of fuel and air and in proximity to ordnance without any possibility of ignition. The components must also be capable of operating under conditions ranging from extreme heat to extreme cold as well as in environments containing salt air and water.

Secure Voice. The capability must be provided to satisfy secure voice communication requirements, relating to R/T nets. Consideration should be given to integrating secure and non-secure nets if it can be accomplished without compromising either method of communication.

Privacy. This is required in conversations dealing with C^2 matters. The system should be capable of allowing users to communicate without having other IC subscribers eavesdropping on sensitive conversation. Privacy is also required on conference calls, but the need for a break-in capability overrides the privacy consideration.

Monitoring Capability. The capability is required to monitor all communications being transmitted or received by a console operator for three reasons: 1) to facilitate information exchange and minimize disruption; 2) it is required by supervisory personnel and key console operators whose duties require them to coordinate the operations of a number of system users; and 3) to allow observation of console operators for training and supervisory purposes.

Now we start defining the operational requirements listed in the second half of the list given in Table 4 These are the features and capabilities that should be incorporated into system and terminal design to satisfy the fundamental requirements just covered.

Single Instrument Access and Selection. The system must provide the capability to communicate on all communication media via either a handset, headset or speaker/microphone and be selectable by console operators based on their communication tasking. This includes the necessity for single microphone access to all communication media.

Single Action Calling. This is required to initiate and receive IC calls by a single control action. This requirement holds for R/T transmissions and announcing systems as well. This capability helps satisfy the requirement for speed and simplicity. Activation of a single push button or switch labelled by subscriber title of work station to initiate a call eliminates the need for a user to recall or look up a subscriber's number or code prior to initiating the call.

Busy Circuit Indication. This capability allows the user to identify or indicate busy IC circuits prior to the call being initiated. This will eliminate the disruptive and distracting effects of signalling subscribers when they are engaged in another call. This also minimizes delay time resulting in operator distraction from tactical displays.

Some IC experts, [Ref. 5: p. 15], feel that both a visual and audible indication are required. This author feels that only one indication is necessary and that it should be visual only, in order to reduce noise levels. With the caller taking positive action to initiate a transmission, he is already looking for a busy signal indication (flashing light). Therefore, he does not need an audible indication to alert him to the situation; as is the case when he is receiving a call.

Incoming Call Alert. This capability alerts users to incoming IC calls through a brief audible alert to prevent their distraction from potentially more critical taskings. An audible vice visual alert does not require the operators to constantly visually monitor their console. When a headset is being used at a console the audible alert should emanate from the earpiece(s) in the headset rather than through a console speaker in order to reduce noise levels.

ID of Calling Party and Urgency of the Call. These two requirements go hand-in-hand. The system must be able to ID the party or the watch station initiating the call in order to screen incoming calls during high tempo operations and also indicate the urgency of the call to enable the user to determine the priority of calls when two or more are received simultaneously. These are two essential requirements for C^2 personnel. They do not have time to respond to calls that are not relevant or time critical during periods of high demand. An additional feature that would be useful, would be the capability to indicate to the calling party what his status is. If, for example, he receives indication that his call is considered a low priority he may terminate his call, thus not only lessening the system load but also freeing himself to do other things. Another use would be if he received a low priority and he felt that was a serious mistake based on the tactical situation he could then invoke call break-in.

Call Override. A call (or ring) override capability is required to alert personnel to an urgent incoming call when they are engaged with another IC call. This function should have priority over all but radio communications in progress at the called station. This capability can be provided by the same capabilities described in the previous requirement. Shipboard personnel prefer call override to the break-in method for the majority of urgent communication exchanges [Ref. 5: p. 15]. The break-in method is disruptive and lacks privacy. Plus, the calling party may disrupt a call that is more urgent.

Break-in. This capability is required to deliver messages of extreme emergency. Although call override may be the preferred method, emergency situations do arise that require immediate access to other users. In such a situation the calling party must be able to gain immediate access to the called party or station by activating a single control and the called party must be able to receive and respond to the call without activating any control or functions.

Call Hold. This is required at the console or terminal to enable IC calls to be temporarily terminated when a more urgent call is to be received or transmitted. This also speeds up the communication exchange by keeping the temporarily terminated console on-line while the urgent call is in process, eliminating the need to re-initiate the call. This is what would occur when the break-in capability is invoked.

Hunt-Not-Busy. This capability is required at vital C^2 nodes, but not necessarily at each individual console, to route incoming IC calls to an idle terminal in watch stations where more that one terminal is implemented for decision making personnel. Implementation of this capability at C^2 consoles is desirable, but only if it can be

selected during initial console set-up and can be easily cancelled at any time [Ref. 8: p.2-12]. One other point, is that this may be desirable for routine calls but not necessarily for urgent or high priority calls. The caller may prefer a busy signal indication prior to initiating his call to allow him to chose call override or break-in capability depending on the situation rather than possibly wasting valuable time being routed to another terminal.

Conference Call. This is required to enable subscribers to communicate simultaneously with two or more other users. Conference calls are necessary for planning and decision making purposes and for coordinating various aspects of C^2.

Instrument Design. This refers to headset design. It should be constructed of light-weight materials to prevent user discomfort during prolonged periods of use. It must also have non-occluding earpieces to prevent masking of face-to-face communications and communications that are monitored over speakers. However, this requirement might necessitate a reduction in background noise that could be interfering with a user's ability to hear properly over the headset. In addition, a split headset capability (a different circuit to each earpiece) must be provided to allow for the monitoring of two circuits simultaneously.

Single Action Transmission. Push-to-talk (PTT) actions are not required for IC calls. Single action calling opens a circuit and no further action is required. Access to announcing circuits should provide the option of spring loaded PTT buttons to provide channel selection or alternate action (non-PTT) buttons. R/T transmissions also require a single action PTT button. Additionally, in order to allow as much freedom of movement to a user as possible, he should have available both foot-operated and hand-operated PTT buttons. The foot pedal would also free the user's hands for other tasks.

Brightness Controls. These controls are required for adjusting the intensity of light used to illuminate terminal displays and control labels. Separate controls are required for displays and labels that vary in design, size, intensity etc.

Volume Controls. These controls are required to adjust the volume of the communications received over the various terminal instruments. Separate controls are needed for adjusting the volume of the headset(s), handset(s) and speaker(s) at each console. A volume control switch is also required for each earpiece of a split headset.

The next chapter contains the description of SNTI. Before going on the reader should ensure the he or she has a firm grasp of, not only the fundamental requirements and operational capabilities of an ideal ISCS, but the reasons why these requirements exist. That is, what is it about today's warfare scenario and the current IC systems installed on U.S Navy surface combatants that lead to potential problems and require a redefining of ISCS needs and standards.

To have such an understanding is important because SNTI is going to be presented from a point of view that attempts to show how well it matches up against the concepts and requirements presented in the first three chapters.

IV. SYSTEME NUMERISE DE TRANSMISSIONS INTERIEURES OR SNTI

Describing and then evaluating the performance of the French built Systeme Numerise de Transmissions Interieures (SNTI) is one of the goals of this thesis. Hopefully the first three chapters prepared you, the reader, to be able to understand the SNTI and how it stands up against the IC needs and requirements discussed earlier.

The French requirements for designing an ISCS encompass many of the same needs identified in the previous chapter. The development of SNTI began with a background study of ISCS requirements in 1970. By 1972, the first working model had been developed and by 1978 the French began first generation development of SNTI for use on their Tripartite Mine Hunter (TMH) program. Second generation development began in 1979 and a working model was developed a year later.

Both the first and second generation systems use the same basic principles and system architecture. The primary difference between the two is that the second generation system consists of four master stations vice only two and is configured with four coaxial cable loops instead of a dual loop configuration.[1] These changes give the second generation system a greater capability and capacity, a more powerful reconfiguration ability and better user unit (console) interface. During discussion of SNTI specifications and capabilities, all data provided can be considered applicable to both generation systems unless otherwise indicated.[2]

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[1] Some SNTI documentation refers to the master station as a pilot station.

[2] The source of all the information presented on SNTI in this thesis, was from a package of unpublished and unauthored material provided by Naval Ocean Systems Command, San Diego, Ca.

A. SNTI GENERALITIES

In its simplest terms, SNTI is a time division multiplex (TDM), the ports of which are distributed over a single transmission carrier consisting of a coax cable which is arranged in a closed loop. This loop system is managed by a master station where the subscribers are connected to the loop through connecting stations; each of which can receive up to 16 different subscribers.[3] Figure 4.1 and Figure 4.2 provide examples of the basic SNTI architecture.

A system directory (a definition of links between subscribers) is stored in the master and connecting stations.

Equipment specific to SNTI include interface units for the automatic telephone, announcement amplifiers and radio transmitter receivers. There are also operator consoles for connection to a shore telephone network. In addition, there are the operational units (consoles/terminals) available for intercom use, radio access and announcement control. With this equipment incorporated into the system, SNTI is able to provide dial telephone service, general announcing service, operational and technical intercom service and radio net distribution.

The operating features of SNTI can be broken down in general terms to four main features. First is the baseband transmission of digitalized information. With a digital system, the choice of baseband (vice broadband) is an obvious one [Ref. 9: p. 332]. Baseband provides the benefit of increased system speed. Also, with the growing concern for increasing capacity of a system comes the need for a high degree of multiplexing to utilize such a capacity; and

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[3] Some SNTI documentation refers to connecting stations as concentrator stations.

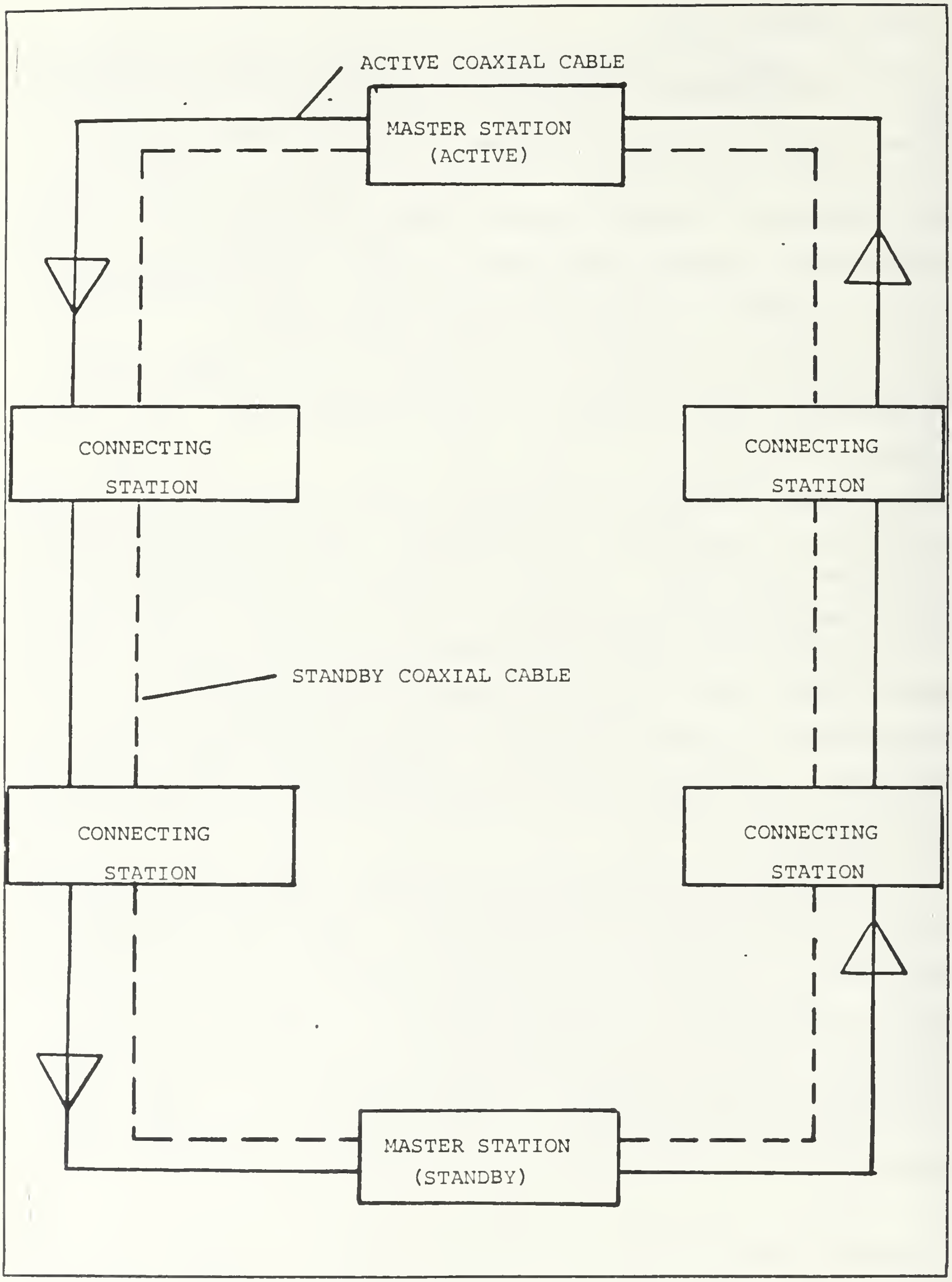


Figure 4.1 SNTI Network Architecture.

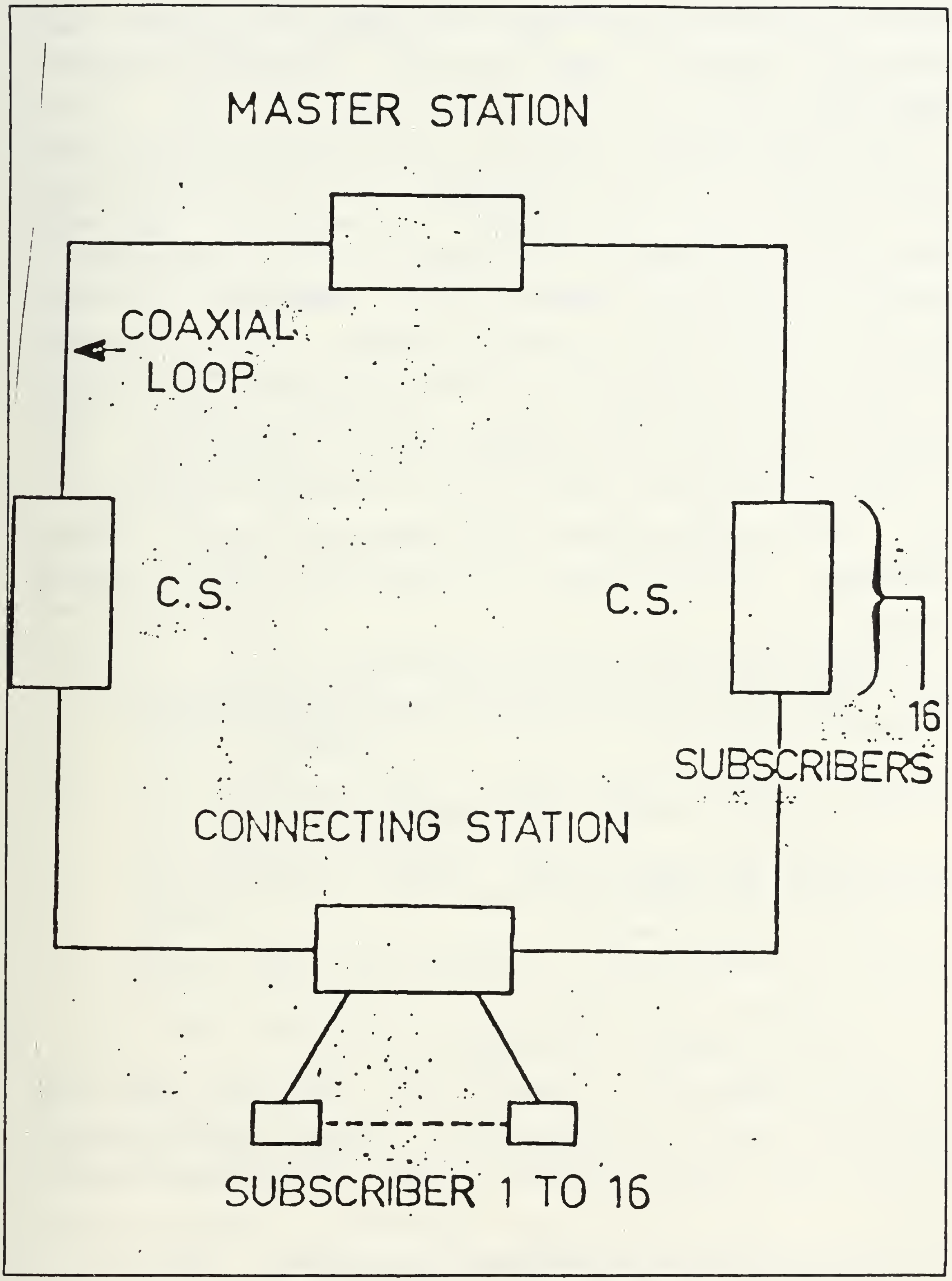


Figure 4.2 SNTI Network Architecture.

this is more easily and cheaply achieved with digital (time-division) rather than analog (frequency-division) techniques.

The second feature is that of synchronous digital multiplexing which, as can be seen from the previous paragraph, goes hand-in-hand with baseband transmission. The next feature is loop organization which aids in the simplicity of operation. The final feature is the capability for automatic reconfiguration in case of damage. This is possible through the use of a continuous self-monitoring system including a backup master station and alternate loop. Both of these topics will be discussed in more detail later.

Before getting into the specifics of SNTI, one needs to know of the criteria that were established prior to system development. The criteria, or SNTI objectives, were as follows:

1. Cable length and weight reduction
2. Transmission of voice and data on the same network
3. Easy connection of subscriber equipment
4. Great flexibility
5. Easy modification of the network
6. High reliability
7. Ease of reconfiguration
8. High level of safety
9. Easy maintenance
10. Low installation costs
11. Improved network integration

With these objectives in mind, along with the needs and requirements identified previously, we will now move on to the next section which provides a more detailed description of SNTI.

B. SNTI SYSTEM DESCRIPTION/SPECIFICATIONS

The SNTI consists of three primary pieces of equipment: master stations, connecting stations and user stations.

This section will start with definitions of each and then attempt to show how they interface with the system as a whole. This will entail a description of other SNTI components as well as specifics on system operating characteristics and parameters. A description of a master station comes first.

Master Stations. The primary purpose of the master station is management of the system or, more specifically, the loop. To do this it generates and inserts into the multiplex the frame alignment codes from which the digital multiplex can be extracted. In conjunction with this, it must also generate a clock frequency that provides transmission delay compensation (i.e., phase control) in order to obtain a one-way closed loop transmission system. This ensures correct phasing of the loop regardless of length. See Figure 4.3 .

Additional function performed by the master stations are:

1. Providing access to the directory required for creating subsystems which conform to the interconnectivity matrix (or grid) laid down in the system specifications.
2. In conjunction with a teleprinter it offers a facility for feeding in data (network changes, special maintenance and testing programs, etc).
3. Exercising continuous supervisory control of all system devices ensuring fault detection and location and indicates fault reports or displays to the teleprinter.
4. Upon a loop interruption it emits signals to trigger an automatic loop reconfiguration.

In normal operation one master station is active and the other(s) are in a standby mode. In a system with more than two master stations, the standby one designated as the primary backup monitors the system in a similar fashion to the on-line station. Each station is backed up by a buffer battery system. This means that in the event of a failure in the main network, it's necessary to switch over to the protected network to maintain operation. The minimum time required to make the switch is 200ms in order to allow for proper re-initialization of the system.

- Time delay compensation
- Frame code and super-frame code insertion
- Loop control
- Network directories broadcasting

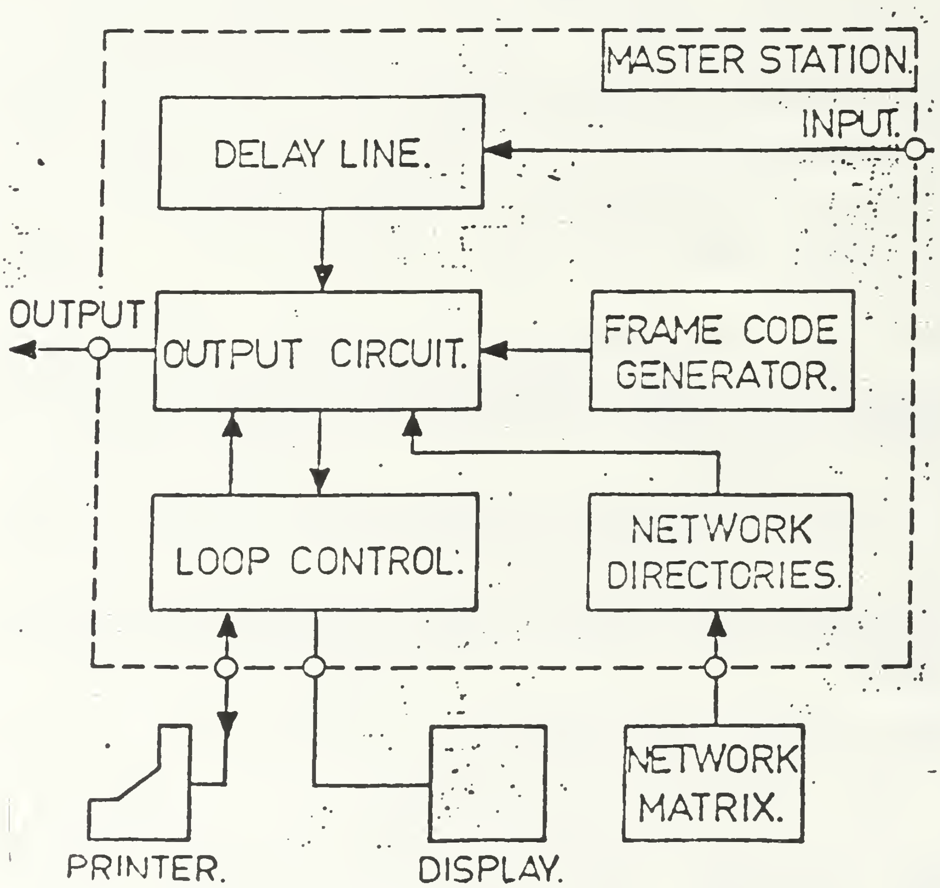


Figure 4.3 Master Station Blocking Diagram.

Connecting Stations. These stations allow for connection of up to 16 subscribers to the loop. It provides these subscribers, or users, with an information input and output facility, allowing signalling and information to be introduced into and taken out of the multiplex. For each user, one or two listening channels and one transmitting channel are available. See Figure 4.4 .

The connecting stations are divided into two parts: common circuits and user terminal interface circuits. The former are the essential part of the station and ensure the following functions:

1. Incoming signal regeneration.
2. Extraction of the time clock signal from the multiplex.
3. Frame and multi-frame synchronization.
4. Real time processing of signalling messages.

The second part, the terminal interface units, are standardized throughout the system and are designed to provide:

1. Two 32 Kbps receiving channel.
2. One 32 Kbps transmitting channel.
3. One incoming signalling channel.
4. One outgoing signalling channel.
5. One 32 KHz clock.
6. The power supply for specific subscriber functions.

As with the master stations, each connecting station is backed up by a buffer battery supply and the same 200ms time period is required for system re-initialization. The connecting stations are also the power supply to the subscribers and their associated functions that are assigned to each station. For example: the subscriber station itself, radio interface, service operator telephone board, etc. The power consumption of each subscriber is included in the power consumption of each station.

User Stations. The purpose of the user stations (or operator console/terminal or subscriber station) is the

- Multiplex interface with read and write circuits
- Subscriber interface; up to 16

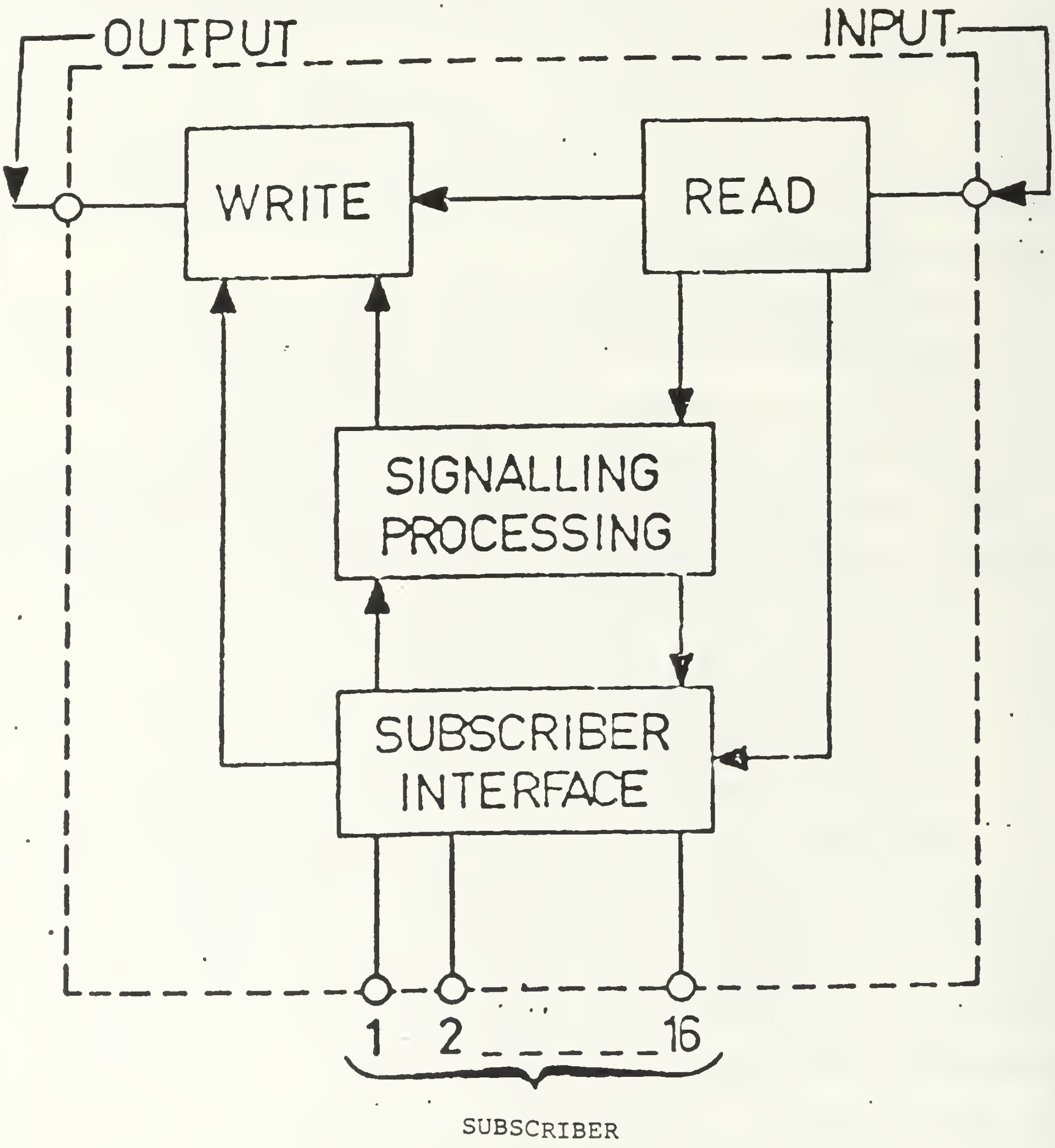


Figure 4.4 Connecting Station Block Diagram.

management of the various communication links through SNTI. These communication links are radio, intercom/conference and announcing/alarm. Each station is comprised of two reception channels and one transmission channel for use in a single or dual function mode. They are also fitted with two pushbuttons for selecting the desired function, one test pushbutton and 19 other general purpose pushbuttons for individually selecting the links provided for in the system directory for that console.[4] Combining these features a standard user station could appear with a console resembling the one described in Table 5 . Two examples of how a user may select up to 19 links from all the available functions is shown in Table 6 .

TABLE 5
OPERATOR CONSOLE FEATURES

- a pushbutton board comprising:
  - 19/8 pushbuttons for link selection on each position
  - two pushbuttons (F1 - F2) for position selection
  - one test pushbutton
  - one PTT pushbutton
- two audio connectors for headset(s) or handset(s)
- a pad for labelling the connection board
- a front panel loudspeaker (SNTI 240 only)

Intercom (point-to-point or conference), radio circuit and announcing or alarm are the functions available. The F1 and F2 positions are dedicated to one of these functions through the station directory. The user can receive

[4] The smaller, 120 channel SNTI systems have only 8 general purpose pushbuttons providing a maximum of 16 links (eight links per function).

TABLE 6

EXAMPLES OF LINK SELECTION

Example 1: Single function use - intercom only.

Sixteen point-to-point intercom links are available, plus three accesses to three separate conference circuits making a total of 19 links.

Example 2: Dual function use - intercom and announcing.

Eight point-to-point links and five accesses to five separate conference circuits in the intercom function are available, plus six announcing links for announcing on five separate networks and for general announcing on all five networks simultaneously, making a total of 19 links.

simultaneously on his headset, or handset, and on the loudspeaker one channel among 19/8 on F1 and one among 19/8 on F2. At any one time the user can have only one connecting in each position. Listening of both the selected channels is simultaneous, but transmission only goes via the actuated channel. With these points in mind a brief description of system operation at an operator console is provided:

When F1 pushbutton is depressed:

1. The operator can call one of 19/8 F1 lines by depressing the corresponding pushbutton.
2. The operator can talk to his F1 correspondent and still listen to both F1 and F2 correspondents.
3. An incoming call via F1 is signalled by the flashing of the corresponding button.
4. An incoming call via F2 is signalled by the flashing of the F2 pushbutton. The operator must then depress the F2 pushbutton and the calling line then flashes on the corresponding pushbutton.
5. The test pushbutton is taken into account by the system only after all link selection pushbuttons are off and the PTT button is off. The status of the function selected is immaterial.

<u>Intercom</u> <u>Network</u>. The intercom units are equipped with voice inputs and outputs, call keys and signalling devices and allow communication with one or several uses on the same

network. The intercom (or interphone) provides point-to-point connections and conference lines for operational and technical department communications. The capacity for the intercom network allows for 30 users to operate as part of this function, each having up to 19 links to be selected among the other possible 29 parties and five conference lines. Refer to Figure 4.5 and Figure 4.6 .

S/P Phone Lines Interface. The purpose of this interface is to connect a S/P phone line to the loop. Each interface is compatible with the use of up to eight S/P headsets connected in parallel. The S/P phone network allows for connections to operational systems and to technical and maintenance systems.

Announcement Interface. The announcing function, via multiple access terminals, provides for either command transmission (general and specific broadcasting of voice orders) or alarm tone transmission (Audio alarms) to one or more loudspeaker networks, each of which is interfaced with the system by means of an announcing interface. The purpose of this interface is to connect announcement low frequency amplifiers to the loop.

Two types of links are part of this function: 1) partial announcing, which is a one-way link between a user and the announcing interface; and 2) general announcing (speech or alarm tone) which is acceptable to a multi-directional link between a user or an alarm channel and all announcing interfaces concerned. In the case of several simultaneous announcing requests, transmission priority is in the following descending order:

1. Alarm announcing
2. General speech announcing
3. Partial announcing

Priority is also assigned to each console with an announcing function. The priority is indicated on the

ASSIGNMENT OF ISCS 120 CHANNELS	NAB	TMH NCX	NOS	REMARKS
Reserved	-	1	0	Reserved channel
Radio interface Radio user unit	10 15	20	1-20	One pair of channels per T/R - odd channel: T - even cnannel: R
Telepnone	32	32	21-52	One channel per telepnone
Unused	-	10	53-62	
Half-duplex conference	2	5	63-67	One channel per conference
Intercom	15	15	68-82	One channel per intercom
Announcing interface Announcing user unit	3 15	5	83-87	One channel per network One general channel
Alarms	3	5	88-92	One channel per alarm
Telepnone service board	3	6	93-98	One pair of channels per external line: - one shared line - two privileged lines
Unused	-	10	99-108	
System tones	6	11	109-119	One channel per tone

NAB = number of subscribers
NCX = number of channels
NOS = cnannel numbers

Figure 4.5 Channel Assignment in the 120 Channel SNTI.

directory or addressing matrix of its connecting station. Three priority levels are assigned. Therefore, in case of access conflict, access will be granted to the predominant type of announcing coming from the highest priority console.

ASSIGNMENT OF ISCS 120 CHANNELS	NAB	NCX	NOS	REMARKS
Reserved	-	1	0	Reserved channel
Radio interface Radio user unit	20 30	40 -	1-40	One pair of channels per T/R - odd channel: T - even channel: R
Intercom Conference user unit	30	30	41-70	
Half-duplex conference		5	71-75	One channel per conference
Announcing interface	5+G	6	76-81	One channel per announcing network
Announcing user unit	30	-		One general announcing cnannel
Telephone	90	20	82-101	Pooled channels: 10 simultaneous links
Telephone service board	3	6	102-107	- One pair of channels for the incoming snared line - Two pairs of channels for two privileged lines
Telephone (extension - snore lines)	2	4	108-111	One pair of channels per additional privileged subscriber
Speech tests	-	2	112-113	Speech test on user units with radio or announcing function only
System tones	-	6	114 115 116 117 118 119	Dial tone Silence Ring-back tone Busy Unavailable Illegal

NAB = number of subscribers
NCX = number of channels
NOS = channel numbers

Figure 4.6 Channels in the 120 Channel SNTI Extension.

The capacity for the announcing network allows for 30 users to operate as part of this function, each having up to 19 links to be selected among the five possible announcing networks, general announcing and alarms if applicable. Refer to Figure 4.5 and Figure 4.6 .

Conference Interfacing. The purpose of this interface is to mix the audio signal of two or four channels. Calls may be established between several parties via the conference function. Only one party may speak at a given moment, while all parties, including the speaker, listen (half-duplex conference). The user initializing the conference has transmission priority. The five possible conferences are of the pre-programmed type. As a result, the operator initializing the conference actuates the corresponding push-button and the system then automatically calls all parties on a pre-established list defined in the programmable system directory.

Radio Interface. This interface corresponds to the equipment which can be directly enclosed in the set itself. The purpose of it is to connect radio equipment to the loop thus enabling the following:

1. Acceptance of an analog frequency (AF) signal coming from the receiver.
2. An AF modulation to be presented to the transmitter.
3. Detection of action on the microphone switch by a radio terminal operator and access on the loop to the transmitter to order the transmission.
4. The pick up of condition information such as transmit order, busy circuit or out of service.

The radio operator terminal is derived from the radio interphone terminals. It enables the operator to have access to the radio links. The terminals giving access to these links permit double listening for the supervision of two radio links or one radio link and one intercom link. The capacity of the radio network allows for 30 users to operate as part of this function, each having up to 19 links

to be selected among the 20 possible radio or transceiver lines.

Modem Interface. The purpose of this interface is to connect modem equipment to the loop.

Telephone Interface. The purpose of this interface is to connect a standard telephone set to the loop. Each interface unit contains a delta encoder/decoder (codec) and code conversion circuits for signalling information. The codec encodes and decodes the voice signals to and from digital form. In addition, this interface interprets the condition of the line, encodes the dialing signal and for an incoming call provides the ringing current. The standardized interface used permits telephone set connection through a junction box which can be included in the telephone set sole.

The dial telephone system has two types of subscribers having access to the system: subscribers using normal dial telephone sets and subscribers using priority or privileged telephone sets. Including both types of subscribers, the system can accommodate up to 90 phone sets, of which four are privileged sets entitled to direct, external, "shore" type access, plus one forwarding set and the telephone service board set (a more detailed description will come later). These features enable the telephone network to provide the following services:

1. A shipboard subscriber set has access to all other sets in the network through simple dialing.
2. Privileged subscriber sets are also provided with external access through double dialing (0 for external).
3. The telephone service board is provided with external access via the shared line.
4. Privileged subscriber sets and the forward set can put calls on hold (by dialing 0), perform dual calls (by dialling a second time) and forward calls on their incoming external line (by putting on hook). In the latter case, they lose their right to external access as long as their line is kept busy by the forwarded call.

A pool of 20 channels providing for 10 simultaneous, internal calls is available to subscribers for onboard phone calls. These channels are picked up and released by the calling party's connecting station. However, the master station supervises the channels of the pool, so as to be able to release them in the event of failure on the part of the calling subscriber or the subscriber's connecting station.

Telephone Service Board. This is also referred to as the Service Operator Telephone Board and is for the sole purpose of management of shore calls through a common line. That is, it manages an external, shared, "shore" type telephone line which contains interfaces of shore type, external lines for two privileged sets (dedicated lines), as well as the interface of the shared external line (a common line). The shore telephone lines are compatible with the Private Automatic Branch Exchange (PABX).

Channels. On this system channel management is conducted two ways: Via a channel pool with random access (e.g., telephones) or by dedicated channels whereby a channel is allocated to a subscriber or a service. Both modes of management can be mixed due to the availability of a signalling channel and loop control provided by the master station. There are also auxiliary channels that provide for maintenance of the availability of the loop through continuous supervision of the entire system to ensure instantaneous fault finding with an alarm indication provided at the master station.

The two modes of channels are allocated to either a user station (intercom, telephone, etc.) or to a service (conference, alarm, etc.). This allows for a maximum system accommodation capacity of 90 shipboard telephones, one telephone service board as defined previously and 90 user station channels. See the listings in Figure 4.5 and Figure 4.6 .

The maximum of a 90 user station channels is assuming the station is in single vice dual function mode providing for up to 30 intercom sets, 30 radio links and 30 announcing/ alarm networks.

Time. This system operates with one master clock along with the necessary number of slave clocks (which varies according to system size).

Communications Loop. SNTI attempts to reduce cabling and provide flexibility for IC by combining into one unique digitalized network the independent IC functions required aboard ship. A 50 Ohm coaxial cable is used to connect the system stations. The benefit of that is in its suitability to baseband signalling. More specifically, for digital signals the 50 Ohm cable suffers less intense reflection from the insertion of taps on the line and provides better immunity against low frequency electromagnetic noise, thereby providing greater system reliability. A minimum of two cables per system are used to provide redundancy. When the active cable between two stations is damaged an automatic reconfiguration occurs via implementation of the second cable (or loop). See Figure 4.7 .

The main principles of the communication loop are: 1) use of time division multiplex (covered in the next section); 2) transmission of the multiplex in baseband; and 3) one-way closed loop transmission. In addition, the loop contains a built-in-test (bit) system for detecting system faults and for identifying faulty stations. Loop failure can be replaced down to the line replaceable unit level.

Link Structure. The coax links are run between the stations to transmit a well defined message - radio link, interphone link, announcing link, etc. Table 7 provides a list of basic structures necessary for a system of intercom links.

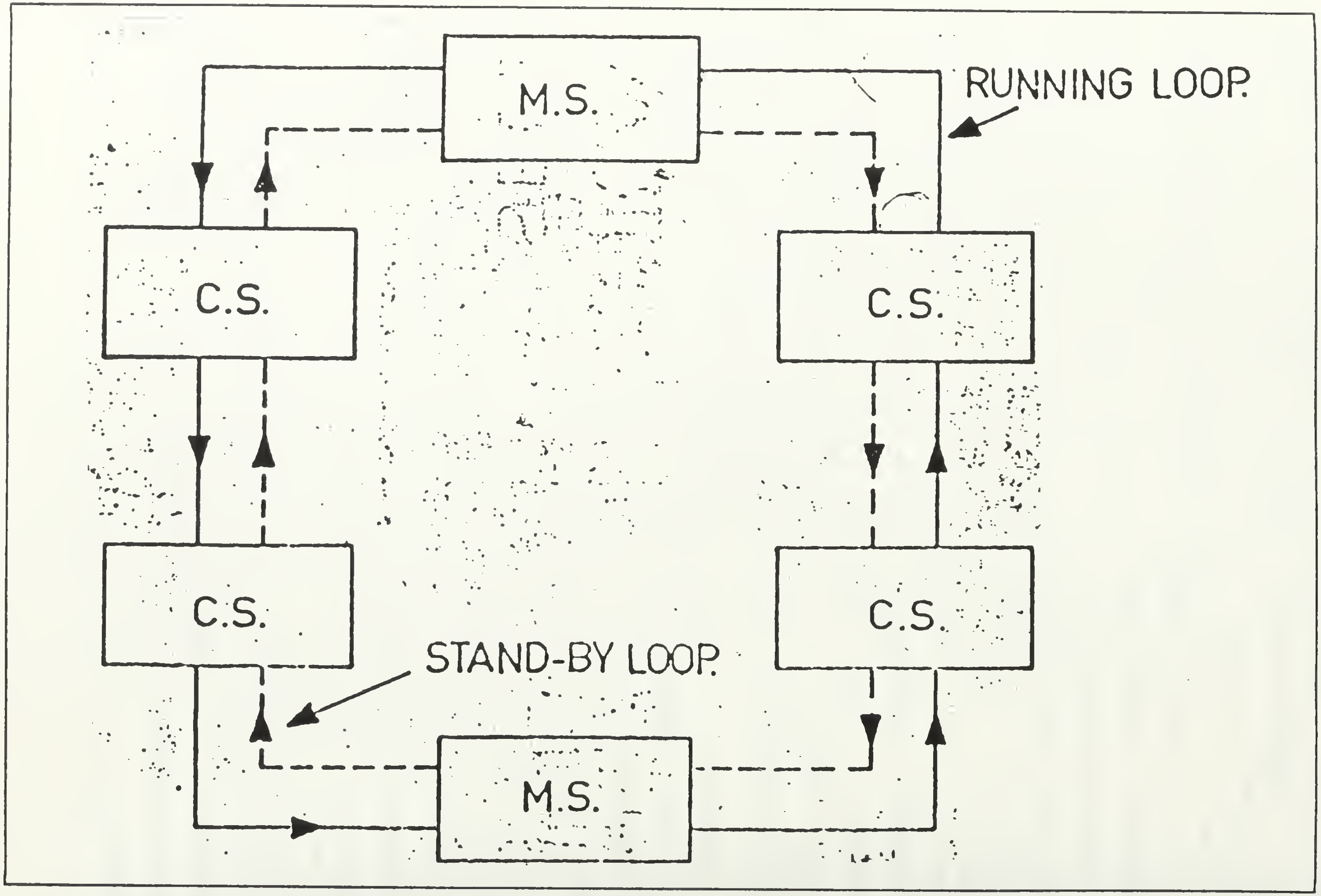
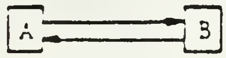
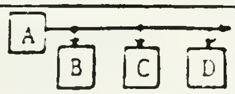
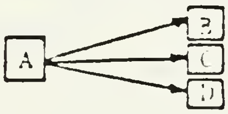
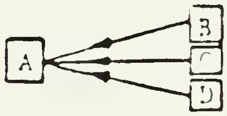
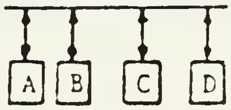


Figure 4.7 Loop Safeguard - Reconfiguration.

TABLE 7

INTERCOM LINK STRUCTURE

Structure	Structure diagram	Analogy with separate networks
push to talk bidirectional point to point		Interphone between two correspondants, special radioservices modulation reception in telephony
Simultaneous point to point bidirectional		Automatic telephone
Transmit unidirectional multipoint		Interphone broadcast
		General broadcast over loudspeaker
Receive unidirectional multipoint		Reception of one or more radio links
Bidirectional multipoint grid		Conference connected interphones Autogenerator telephones

<u>Terminal</u> (<u>User</u>)<u>/Connecting</u> <u>Station</u> <u>Interface</u>. The terminal, or user, interface is designed to satisfy all operational voice terminal constraints. These operational terminals perform the following functions: intercom, radio access, general announcing or any combination of two of them. The interface itself consists of the following wires:

1. Receiver channel one
2. Receiver channel two
3. Transmit channel
4. Clock
5. Terminal input signalling

6. Terminal output signalling
7. Common channel
8. 12 volt DC power
9. Ring voltage
10. Terminal recognition
11. Reset

The connecting station - terminal interconnection is obtained by seven wires , the purpose of which are given in Figure 4.8, with the arrows indicating the direction of information flow.

	Connecting Station	Terminal
- Transmitted data	<------------------	
- Received data one	------------------>	
- Received data two	------------------>	
- Received signalling	------------------>	
- Transmitted signalling	<------------------	
- Time base (clock)	------------------>	
- 12 volt DC power supply	------------------>	

Figure 4.8 Connnecting Station - Terminal Connection.

This type of connection enables any terminal to receive two simultaneous calls and leads to maximum simplification of circuits available in the terminal and in the connecting station. The following points deal with this interface/ connection:

1. The interface supposes that all data exchanged between the connecting station and the user station has been digitalized.
2. The time base (clock) which times the data exchange is at a 32 KHz frequency.
3. The connecting station regularly interrogates the user stations to which it is connected. It initiates all signalling exchanges.

4. The exchange procedure is a start/stop procedure for the signalling of words. The words belong to an ASCII alphabet of seven bits to which one parity bit is added thus giving an eight bit code.

5. The signalling messages are normally exchanged at a 32 Kbps modulation rate, however, the terminal (user station) is designed so that it is always the clock signal sent by the connecting station which is used to set the signalling rate.

6. The signal digitalization process is the 32 Kbps modulation rate, however, the terminal is designed to receive a clock signal which can attain 128 KHz. This has the effect of enabling a digitalization by a process which has a maximum binary rate of 132 Kbps vice 32 Kbps.

Signalling Exchanges. The signalling exchanges between user and connecting stations are performed in an asynchronous mode requiring each ASCII code word to be preceded by a single start bit and followed by two stop bits. Figure 4.9 shows the basic structure of the exchanged word.

The exchanges are based on the acknowledgement/no acknowledgement (ACK/NACK) procedure. With initialization of signalling exchanges assigned to it, the connecting station interrogates its connected user stations one by one within a given period of time that is compatible with the reaction time of the station operator. In order to guarantee exchanges of limited duration, the number of words exchanged in a sequence during an interrogation remains limited and is defined for each procedure.

Directory Specifications. Data used to describe the SNTI system directory are divided into three groups: 1) data contained in the diode matrix board of the master stations; 2) data contained in the diode matrix board of each connecting station; and 3) common data contained in the directory memory (2K REPROM) common to all connecting and master stations. The data contained at the master stations consists of station addresses and system parameters required for reconfiguration, remote supervision and operation. The

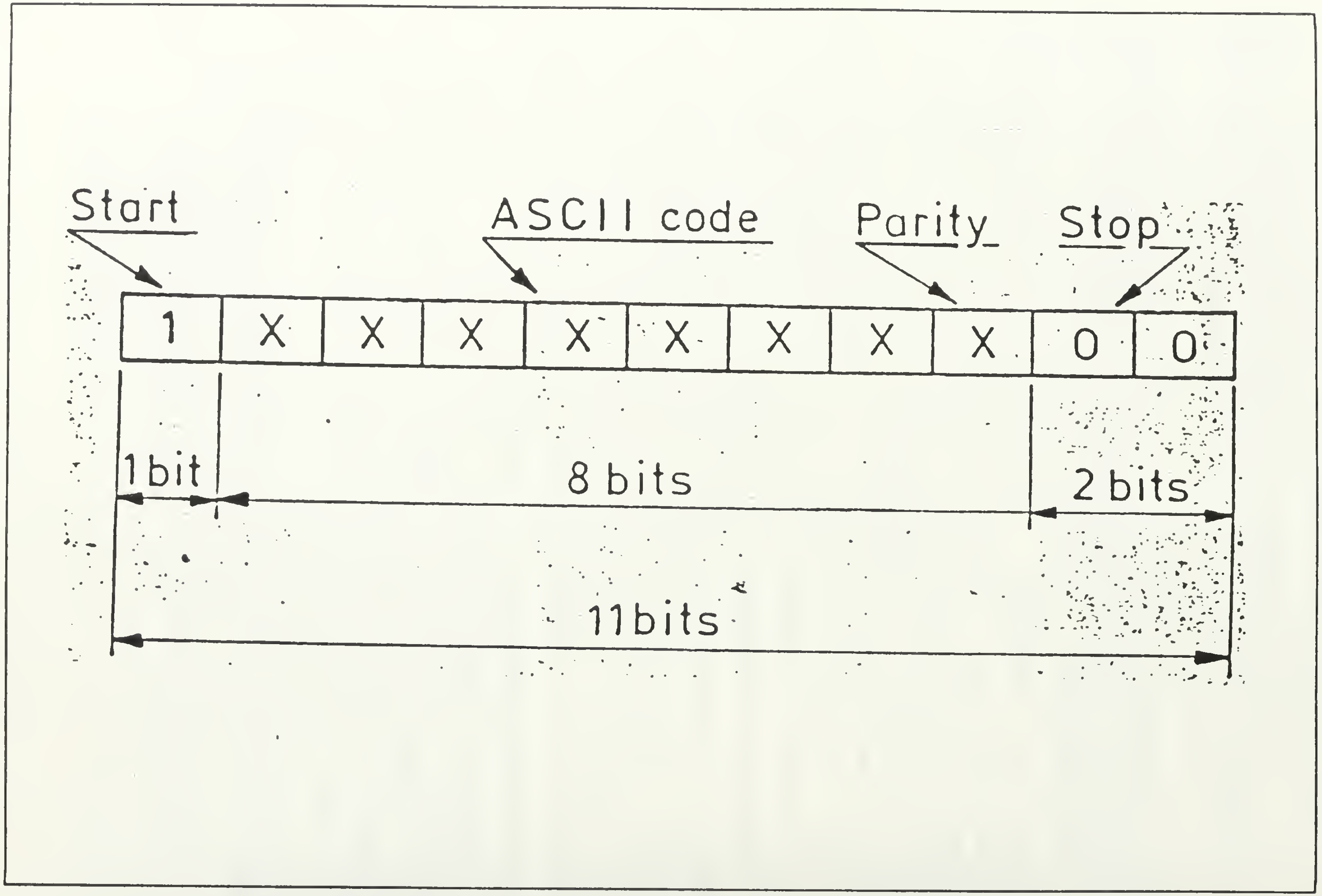


Figure 4.9 ASCII Code Word.

data at the connecting stations consists of the addresses and parameters of the subscribers connected to that station. The third part of the directory defines links and facilities authorized for all system connected subscribers. Unlike the data at the master and connecting stations which is user programmable at each station via built-in diode matrices, the final part of the directory is common to all stations and is stored in specific re-programmable memory.

The way this system is established, in a very basic sense, is as follows. First of all, addresses must be allocated to each subscriber. This is done in the connecting printed circuit board of the connecting station by setting call numbers on a diode matrix. Then the inter-connection grids laid down in the SNTI specifications are reproduced on one or more matrices, which can be located inside the master station (usually smaller systems) or outside the master station (larger systems).

Teleprinter. The teleprinter(s) is connected to the master station to assist in management of the loop. It provides readouts on control status, tests and alarms and indicates fault location. Usually one teleprinter is connected to two master stations.

C. MULTIPLEXING

The operation of SNTI is based on the principle of Time Division Multiplexing (TDM). This procedure, simply put, allows for the division of a transmission medium into two or more channels by allotting the medium to several different information channels, one at a time. Though some comments concerning TDM were made earlier, before getting into the specifics of multiplexing a brief review of general multiplexing techniques is offered. See Ref 9 .

1. Principles of TDM

Time division multiplexing requires that every signal be in a digital form prior to transmission. The digital signal is then inserted into the multiplex circulating on the medium (the coax loop in SNTI). A TDM can consist of: 1) a bit organization - one bit per time slot; 2) a block organization - one block per time slot; or 3) a mixed organization - a combination of the two.

Here is how TDM works. There are a given number of digital signals to be transmitted. They are identical in bit rate but, need not be synchronized. These signals are sampled by rotation.

The sampling rate is determined by a common clock whose frequency is a multiple of the bit rate of any individual channel. A sample is then removed from each offered signal in sequence and the process repeats. Figure 4.10 provides an example of this process.

The sampled signals are then placed end-to-end to form an aggregate signal or multiplex. Each slot of the multiplex contains information (the sample) from a channel. The system needs to know what channel that information is from. This is accomplished by counting the sample's position relative to a synchronization (sync) signal, also called an alignment code.

One alignment code and one sample from all the channels together form a frame. Therefore, the frame alignment code equates to the sync code.

To extract a particular channel, a clock signal is synchronized with the multiplex frame and a counter, using the frame sync code, counts off the required slot. The signal is then extracted from the slot. The sequence is

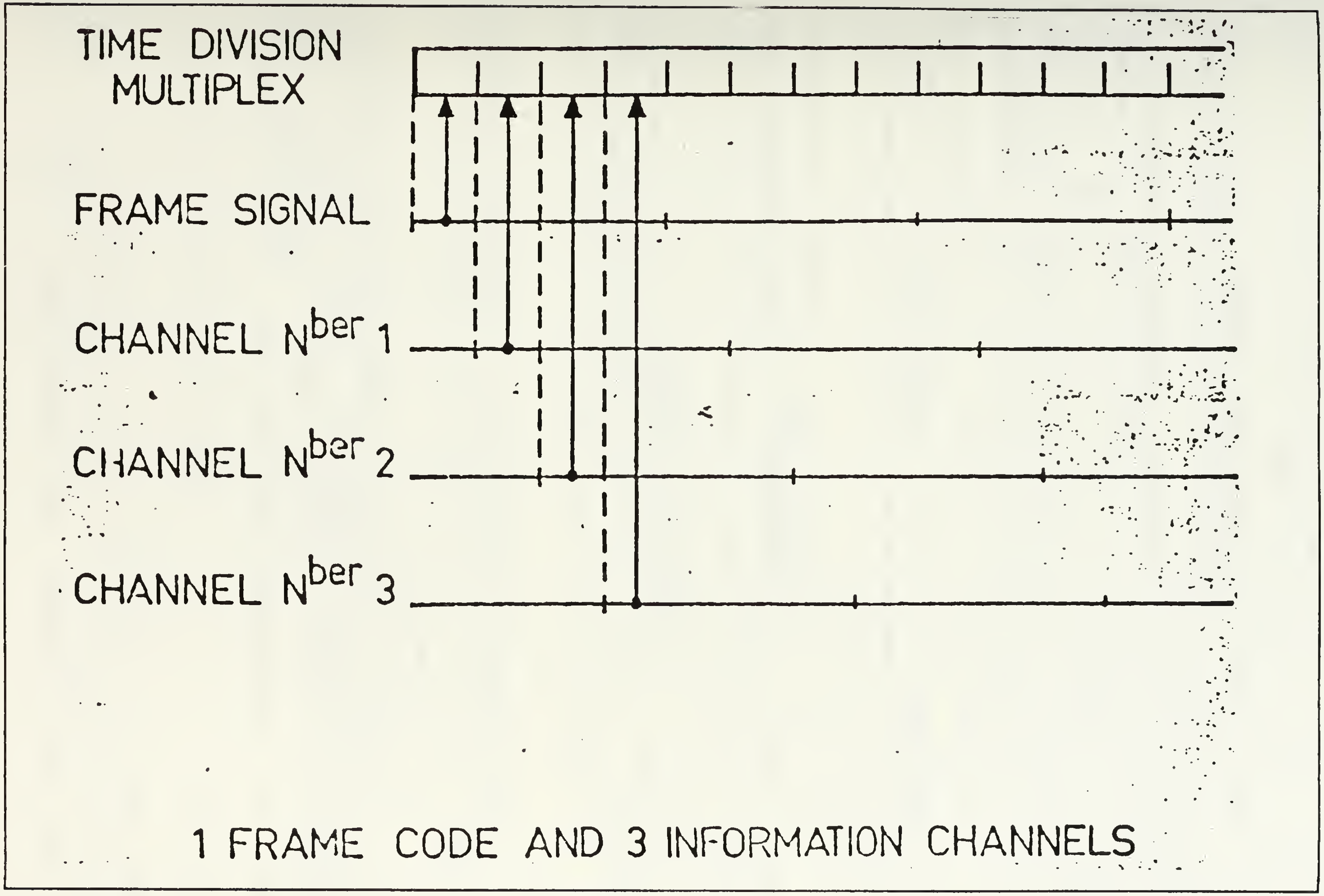


Figure 4.10 Principle of Synchronous TDM.

repeated and the extracts are place end-to-end as they are removed. This reproduces the original signal. Now this technique will be applied to SNTI.

2. <u>The Multiplex Structure Used in SNTI</u>

The multiplex for this system (120 channel system) is required to carry two kinds of information. The first is made up of digitalized voice signals and other data between system subscribers. Voice signals are digitalized by use of Delta Modulation (DM) at a bit rate of 32 Kbps. At this bit rate, DM provides a very good quality voice transmission (i.e., bandwidth from 300 - 3400 Hz). The transmission code of the multiplex is baseband in a split-phase code which eliminates the DC component and contains the information to extract the clock signal.

The other kind of information carried consists of signalling data. This includes: 1) data to establish and terminate connection between subscribers; 2) supervisory, monitoring and reconfiguration messages; 3) data to establish messages; and 4) frame codes to recognize and separate information. The bit rate of the signalling channel is 875 bps; as compared to the basic common channel bit rate of 32 Kbps.

The multiplex used by SNTI is based on a frame of 128 slots (or bits) on a bit-by-bit basis (one bit per slot). See figure 4.11 .

The first 120 bits of each frame are used to transmit the proper information. These 120 time slots correspond to the 120 channels (again, the smaller SNTI system) and the remaining eight bits form a frame block for

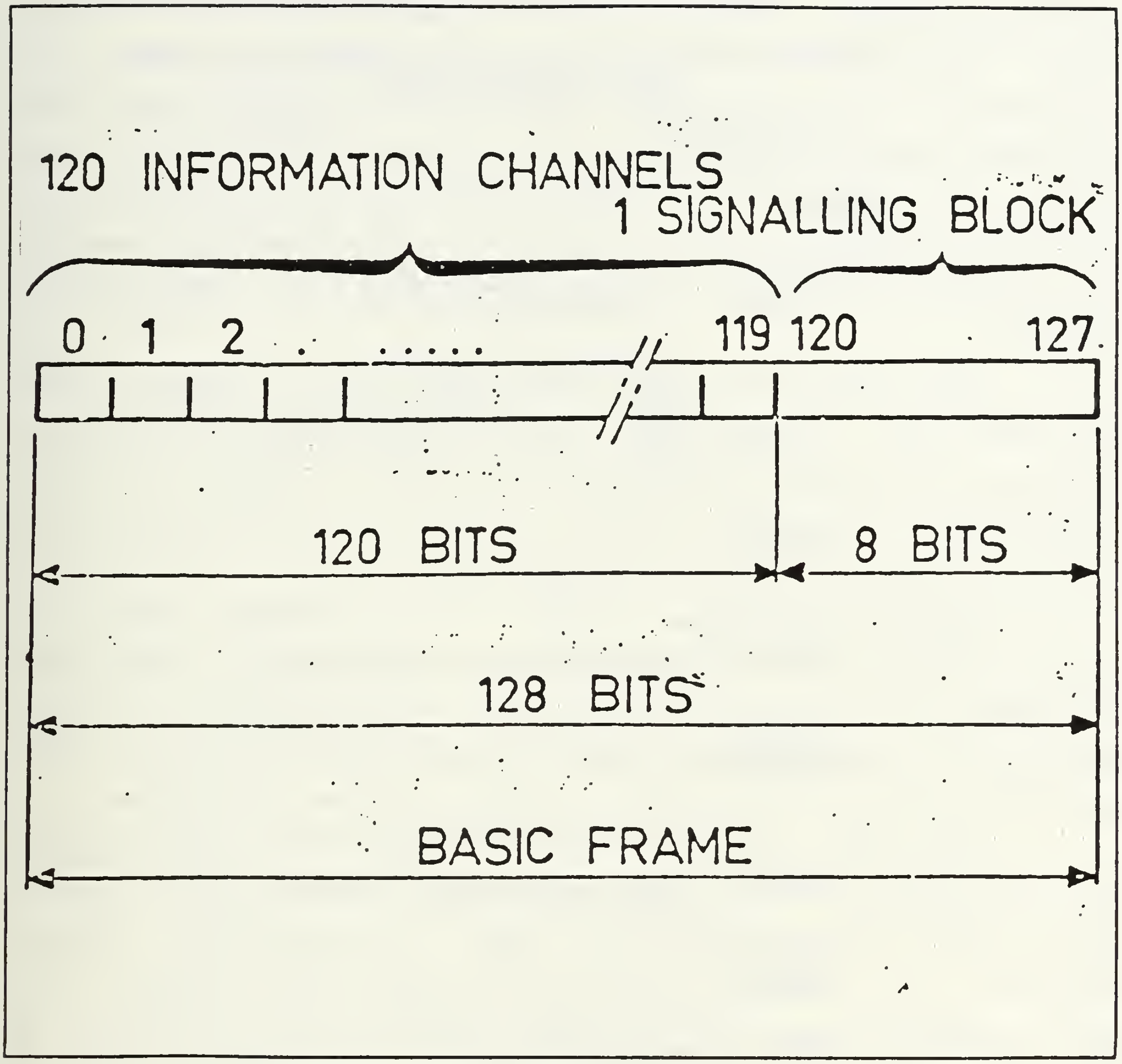


Figure 4.11 SNTI Basic Frame.

alignment, signalling and to route control messages. The bit rate per channel sampled is 32 Kbps, making the overall bit rate of the frame

$$128 \text{ bits} \times 32 \text{ Kbps} = 4096 \text{ Kbps} \qquad \text{(eqn 4.1)}$$

The frame block is used only once per eight frames and is specifically responsible for transmitting the frame code or sync, multi-frame code, channel signalling and

auxiliary channel signalling (for supervision, directory, etc.). The seven blocks of the intermediate frames are dedicated to signalling and order-wire messages which are technical message signals. The multiplex technique is per bit for the common information channel and per block for the signalling channel. This means that the signalling channel is sampled at a much slower rate than the information channel.

This eight bit block, or byte, is followed by the 120 time slots. Each time slot has the duration necessary to obtain the basic communication channel. What this says, is that each frame in renewed at the rate of sampling used for DM (32 Kbps). Refer to Figure 4.12 .

Delta Modulation (DM). The method used for converting the analog voice signals to a digital signal for insertion into the multiplex is referred to as Delta Modulation. The following description from [Ref. 9: p. 84] provides a basic description of this encoding technique.

With DM, the analog voice signals are approximated by a staircase function that moves up or down by one quantization level at each sampling time. The important characteristic of a staircase function is that it is binary - at each sampling time the function moves up or down by a constant amount, thus allowing for a single binary digit output for each sample. In essence, a bit stream is produced by approximating the derivative of the analog signal rather than its amplitude. A one is generated if the staircase function is to go up during the next sampling interval; a zero is generated otherwise. See Figure 4.13 .

The transition that occurs at each sampling instant is chosen so that the staircase function tracks the original analog waveform as closely as possible. For transmission the following occurs. At each sampling instant, the analog input is compared to the most recent value of the

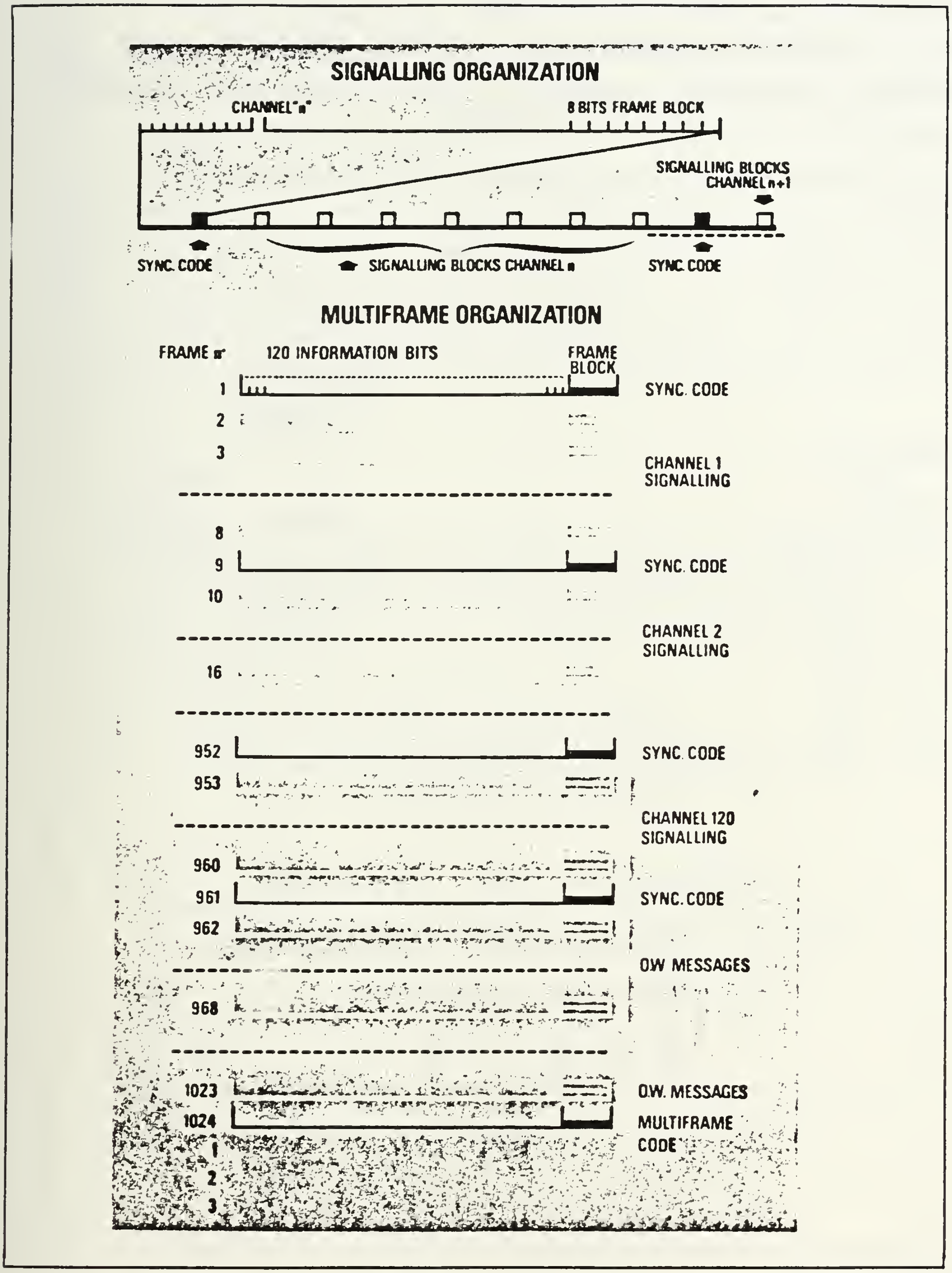


Figure 4.12   The SNTI Multiplex Structure.

approximating staircase function. If the value of the sampled waveform exceeds that of the function a one is generated; otherwise a zero. This binary value is then transmitted as the next output digit.

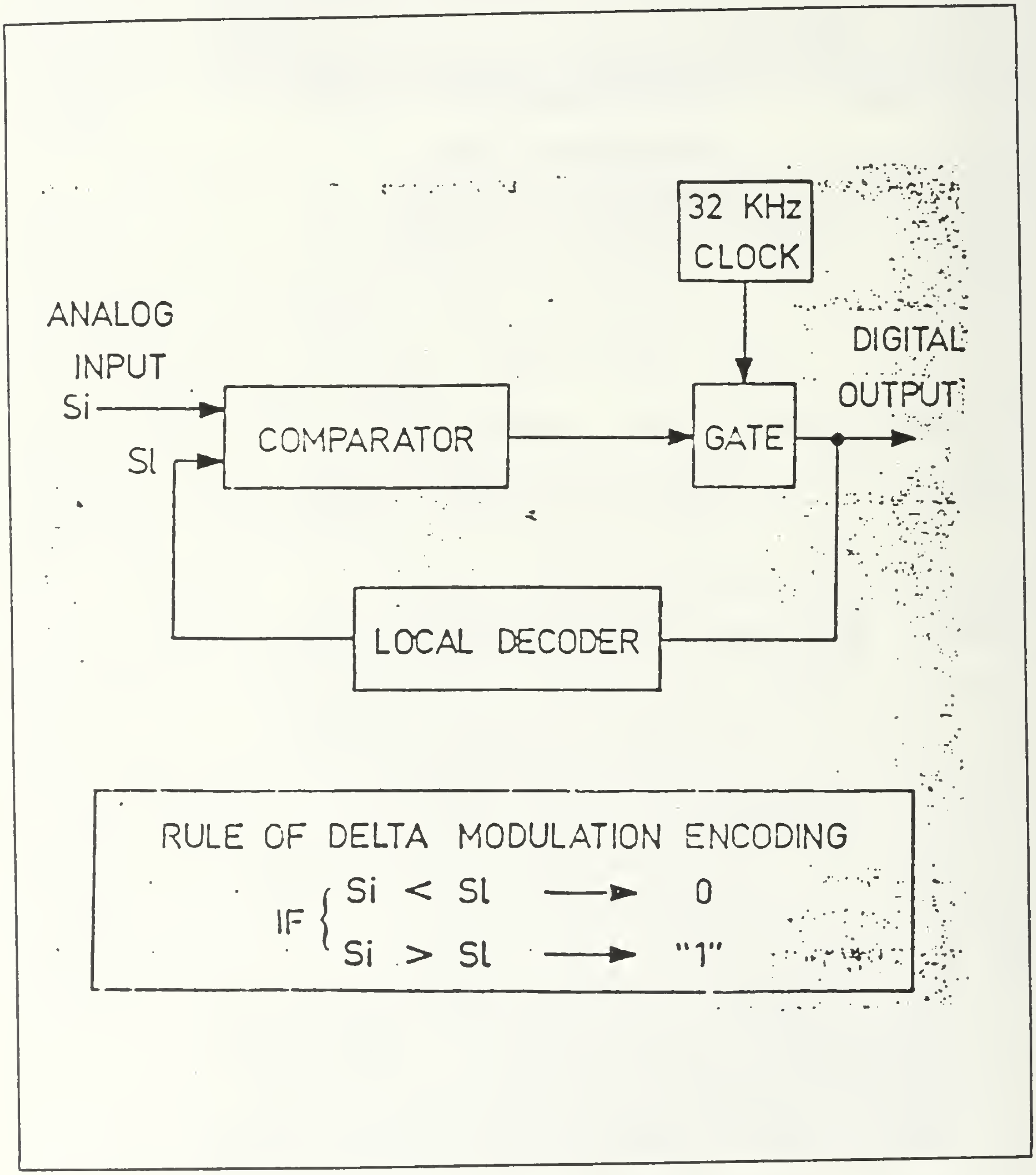


Figure 4.13 DM Encoding Principle.

It should be noted that a principle advantage of DM over Pulse Code Modulation (another popular analog-digital conversion technique) is the simplicity of its implementation, a design criteria for ISCS.

The description of TDM just provided contained operating parameters used in the smaller version of the SNTI, the two master station, 120 channel system. Though some of the operating parameters are different, the TDM principles are the same for the larger, SNTI-240 system. For a comparison of the two system's operating characteristics see Table 4.14 and Table 4.15 .

Information channel bit rate	32 Kbps
Number of information channels	120
Frame code repetition rate	4000/sec
Frame code length	8 bits
Multi-frame code repetition rate	31.25/sec
Bit rate of each channel signalling	1750 bps
Bit rate of auxiliary signalling channels ..	12250 bps

Figure 4.14 SNTI-120 Parameters.

Information channel bit rate	32 Kbps
Number of information channels	240
Frame code repetition rate	4000/sec
Frame code length	8 bits
Multi-frame repetition rate	15.625/sec
Bit rate of each channel signalling	1792 bps
Bit rate of auxiliary signalling channels ..	26880 bps

Figure 4.15 SNTI-240 Parameters.

V. ANALYSIS OF SNTI

Besides being capable of meeting the design requirements specified for the system, SNTI must be able to satisfy design analysts and cost analysts with respect to the question of vulnerability. This vulnerability concept relates to system design, cost and performance.

For example, the more stations in SNTI the less vulnerable it is to being destroyed by a single missile hit. However, more stations probably results in an increase in system costs and it may or may not have a positive effect on system performance.

Therefore, an analysis of vulnerability costs weighs the pros and cons of these three factors against one another. Does the addition of more stations justify an increase in cost? Does this cost result in improved performance? Do production costs drop with more stations and, if so, what is the optimal number of stations to be included in the system? These are just a few of the types of questions that need to be answered.

A. VULNERABILITY COSTS

In determining how to measure the cost of vulnerability with respect to a two (or more) output cost function, it is necessary to understand the relationships between single output functions and multiple output functions. This requires a knowledge of the characteristics of an output function, such as economies of scope, ray cost behavior and the scale effect [Ref. 10]. Before analyzing these factors some important assumptions need to be stated and the input and output variables defined.

What is the cost of vulnerability? It can be equated to the cost of consolidation. That is, the more consolidated

the SNTI is (fewer master stations and connecting stations) the greater is its vulnerability. And obviously, the greater the number and the greater the dispersal of these stations the less the vulnerability of the SNTI. As will be shown, the difference between the cost of consolidating communication requirements (or joint production) and the cost of dispersing these requirements (or separate single production) is the cost of vulnerability.

In this model there are two outputs, labeled I_1 and I_2. The amount or degree of connectivity between the masterstations and connecting stations (I_1) can be defined as their ability to communicate with each other or, put another way, their interoperability. The other output (I_2) is made up of all the other reasonable outputs of these stations.

The input variables for a SNTI (or any ISCS for that matter) are numerous, but a short definition of a few of the more vital ones that could be used in this model are listed below:

1. CHANNEL CAPACITY: the number of channels available and their transmit/receive capability.
2. FREQUENCY ASSIGNMENT: bandwidth, usage and capacity.
3. TRANSMISSION RATE: from the start of send to the completion of receive.
4. TRANSMISSION MEDIUMS: telephone, intercom or announcing and radio transmissions.
5. ECCM CAPABILITY: ability to avoid a "softkill."
6. USER LOCATIONS: geographic position of user stations with respect to each other.
7. NODAL LOCATIONS: locations of master(s) and connecting stations.
8. USER - USER NEEDLINES: communication requirements between users.
9. NODE - NODE NEEDLINES: communication requirements between master station(s) and connecting stations.
10. COMSEC: communications security requirements.

Values are assigned to these variables either arbitrarily (though seldom), based on historical data, statistically or based on relative importance. The cost to achieve

the desired level of each variable is then inputed into the cost function.

With respect to vulnerability, it's obvious that the greater the number and the greater the dispersal of master(s) and connecting stations, the less vulnerable is the SNTI. For this to be economically prudent, the cost of joint production (all communications through one connecting station with only one master station) must be greater than the cost of separate single product production (two or more connecting stations plus a backup master station). This situation is categorized by diseconomies of scope. However, by their nature, ISCS exhibit just the opposite - economies of scope; where joint production costs less. The heavy emphasis on the use of shared resources (CPU's) and collective resources (multi-channel connecting stations) tends to generate economies of scale. Figures 5.1 and 5.2 provide graphical representation of economies of scope.

The funnel shaped design in Figure 5.1, widens as the output product levels (I_1,I_2) increase. A given product mix slices across the funnel and is shown by the curve AGFB. Since this funnel opens upward, the middle of the slice (pt. G) is lower than the ends (points A and B) which indicates it cost less to produce the two outputs jointly, $C(I_1,I_2)$, than separately, $C(I_1)+C(I_2)$. Therefore, it exhibits economies of scope. If the funnel were to be flipped over, then pt. G would be higher than the ends of the slice, points A and B, indicating joint production (a single connecting station) is more costly and exhibiting diseconomies of scope.

Concurrent with this is the concept of "the index for the degree of economies/diseconomies of scope," $SC(I_1,I_2)$. This is the relative decrease/increase that results from joint vice separate production.

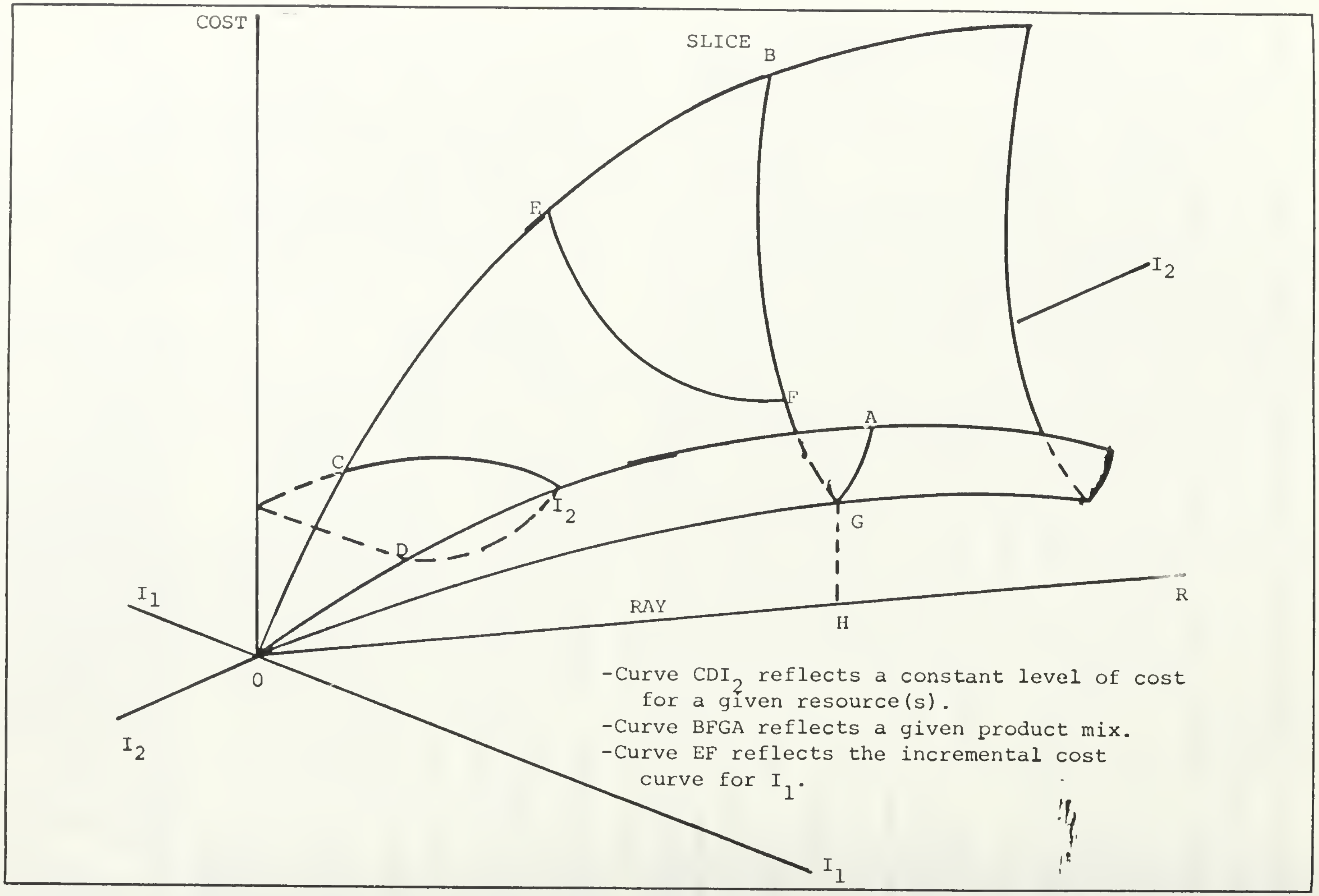


Figure 5.1 Multiple Product Cost Function.

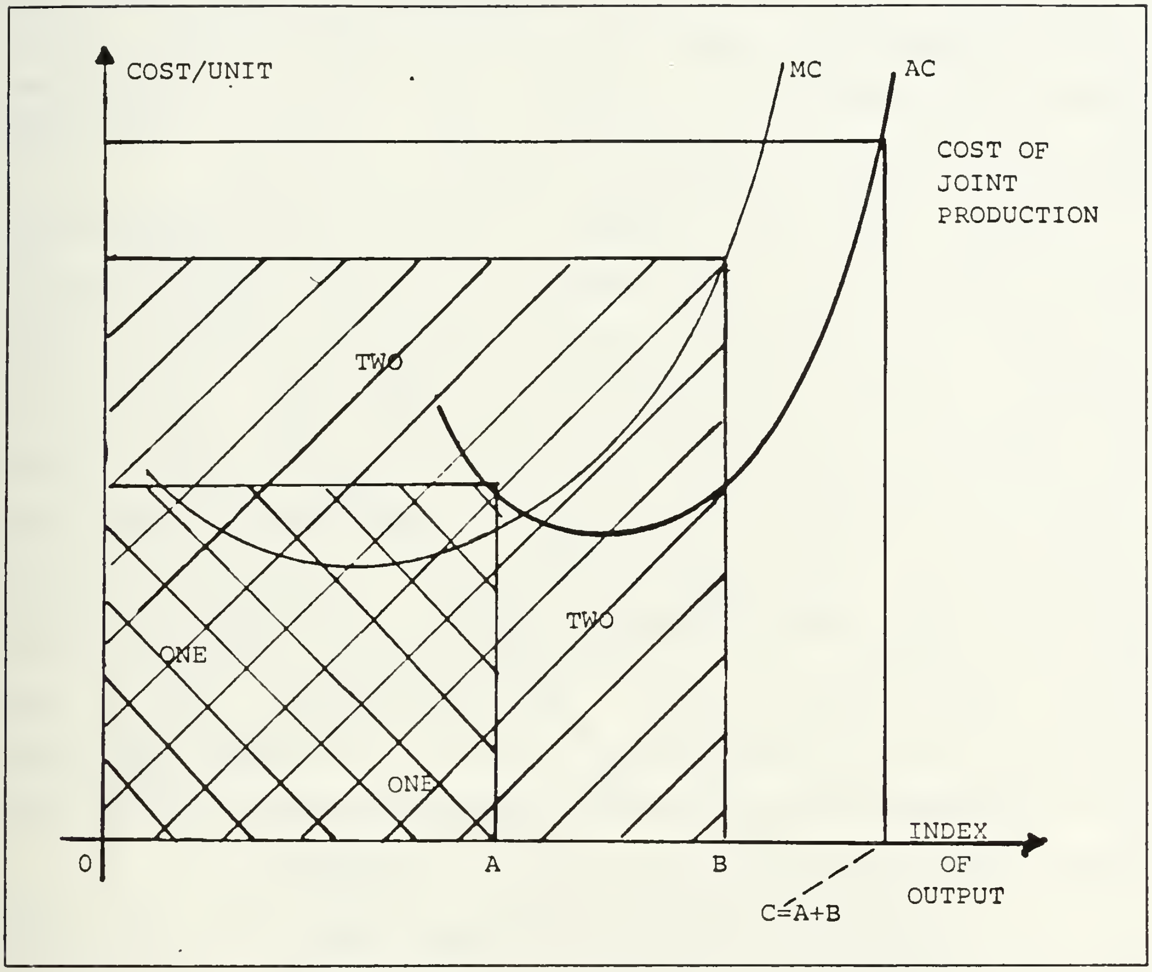


Figure 5.2 Cost of Production.

Therefore, if either

$$C(I_1,I_2)<C(I_1)+C(I_2) \qquad \text{(eqn 5.1)}$$

or

$$SC(I_1,I_2)=(C(I_1)+C(I_2)-C(I_1,I_2))/C(I_1,I_2))>0 \qquad \text{(eqn 5.2)}$$

you have economies of scope. If the inequalities are reversed the result is diseconomies of scope.

In Figure 5.2, the cost of production for one connecting station (shaded area one) plus the cost of production for a second connecting station (shaded area two) is greater than the cost of joint production with a single connecting station, therefore displaying economies of scope.

Another important concept in determining vulnerability cost is that of ray cost behavior. Any ray, such as ray OR in Figure 5.1 represents a fixed proportion between the two products. This fixed proportion is given by the ratio of the length of a line segment from the axis I_1 to ray OR and from the line segment from ray OR to the axis I_2 for a given product mix (I_1,I_2). There are as many rays as there are product mixes. By plotting ray average cost (RAC) and ray marginal cost (RMC) a minimum RAC can identified. Minimum RAC is located at the point of intersection between the RAC curve and the RMC curve. Idealistically, this is the optimum level of production, though it's seldom attained. If the minimum RAC points are mapped out graphically, they form a curve labelled the M-locus. See Figure 5.3 .

If the required output level is inside this curve then only one production activity is needed. If it is outside or to the right of the curve then two or more activities (connecting stations) are needed.

The ratio of RAC to RMC also defines the scale effect. The nature of returns to scale (Sn) is defined by this ratio. If $Sn>1$ you have increasing returns to scale and therefore decreasing RAC. If $Sn<1$ you get decreasing returns to scale and increasing RAC. When $Sn=1$, returns to scale are constant and RAC=RMC.

By taking the cost characteristics and their relationships just mentioned, one can measure the cost of vulnerability. Figure 5.4 shows the RAC and RMC for two selected product mixes. In figure 5.5 the sum of their cost is presented graphically. In Figure 5.6 the cost associated

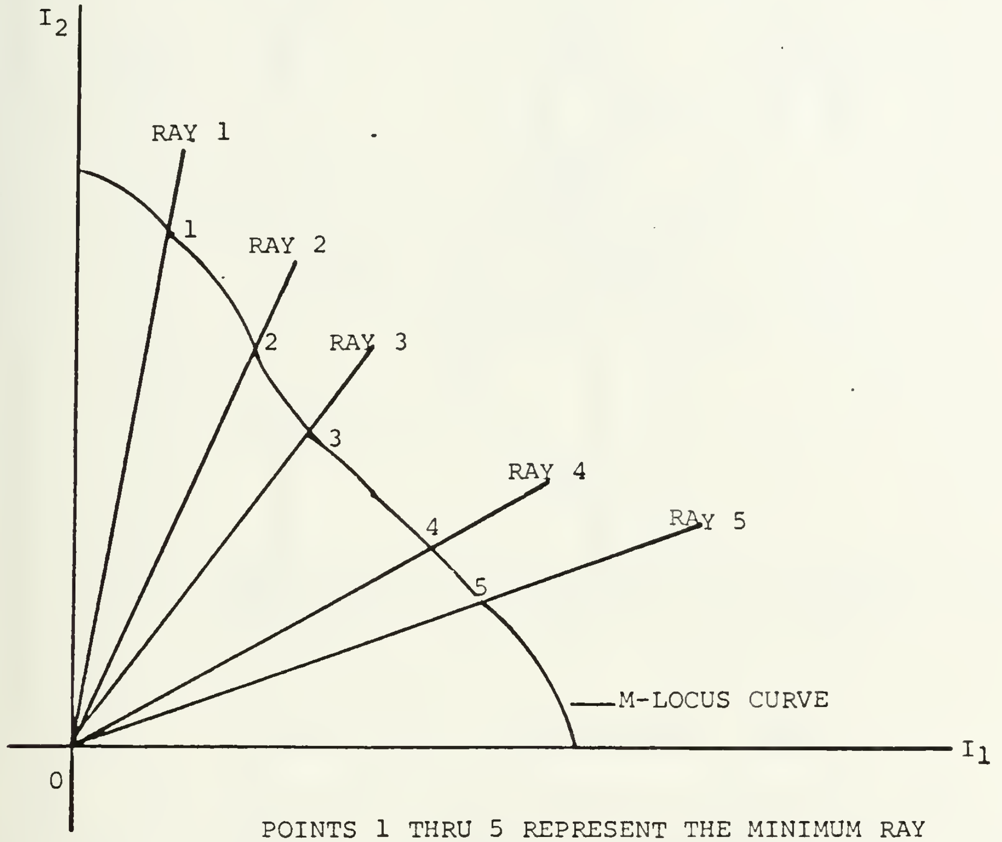


Figure 5.3 M-Locus.

with production on each ray is indicated by points C_1, C_2 (the sum of the costs for rays one and three) and C_3.

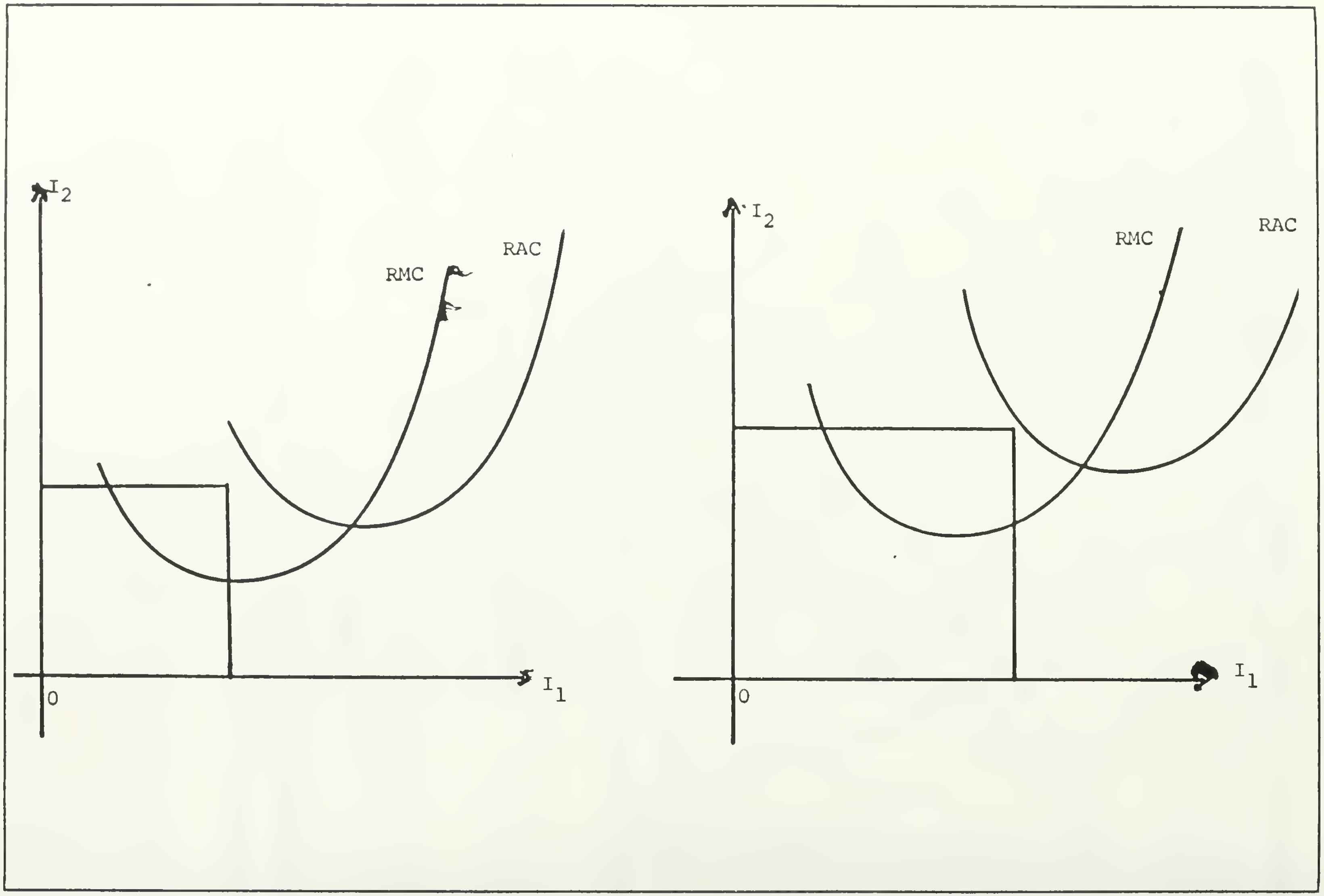


Figure 5.4 Ray Costing - Individual.

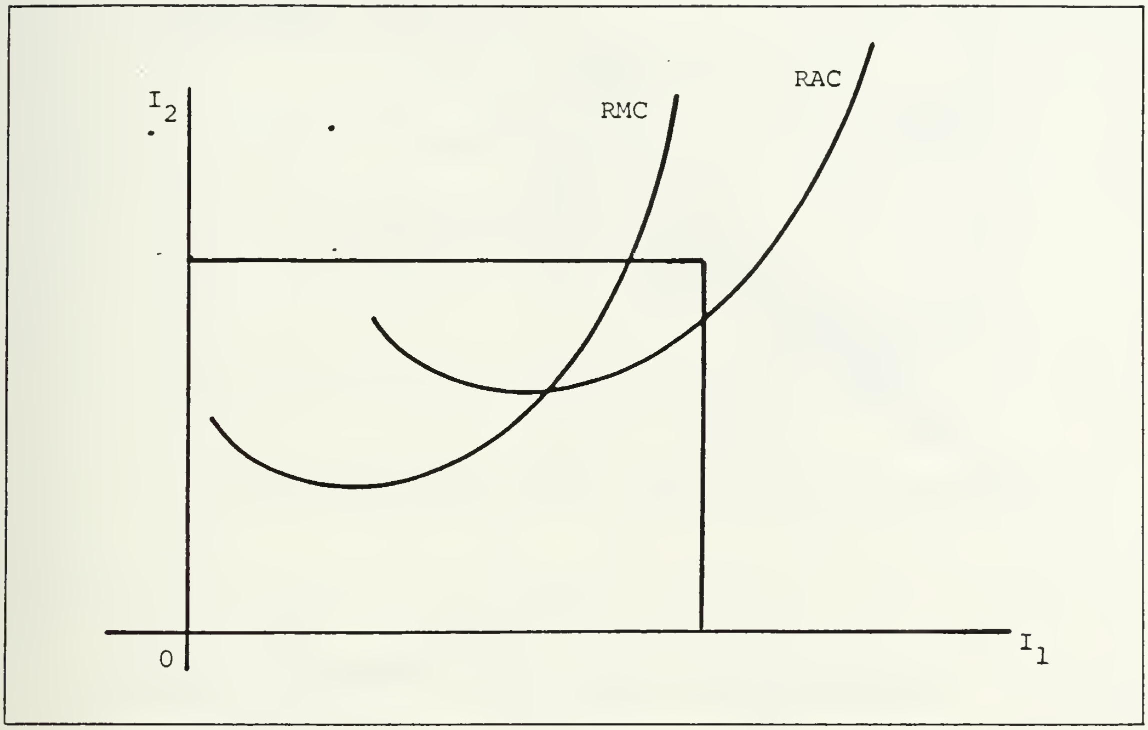


Figure 5.5 Ray Costing - Sum.

The cost associated with C_2 is compared to the output production costs of a single unit or, in this model, a single connecting station. The difference between the two costs is the cost of vulnerability. Figure 5.7, showing economies of scope, provides a graphic representation of the measurement of vulnerability costs.

B. SYSTEM EFFECTIVENESS

Measuring system effectiveness is not a simple yes-no proposition. Accepting the fact that an ISCS can perform a specific function is all well and good, but what is more important is how well it performs that function.

A number of inputs (system parameters) go into supporting a function in order for it to satisfy an outcome (requirement of the system). Today's ISCS have numerous requirements to meet and it is often the case that some system parameters have to be sacrificed in order to make the

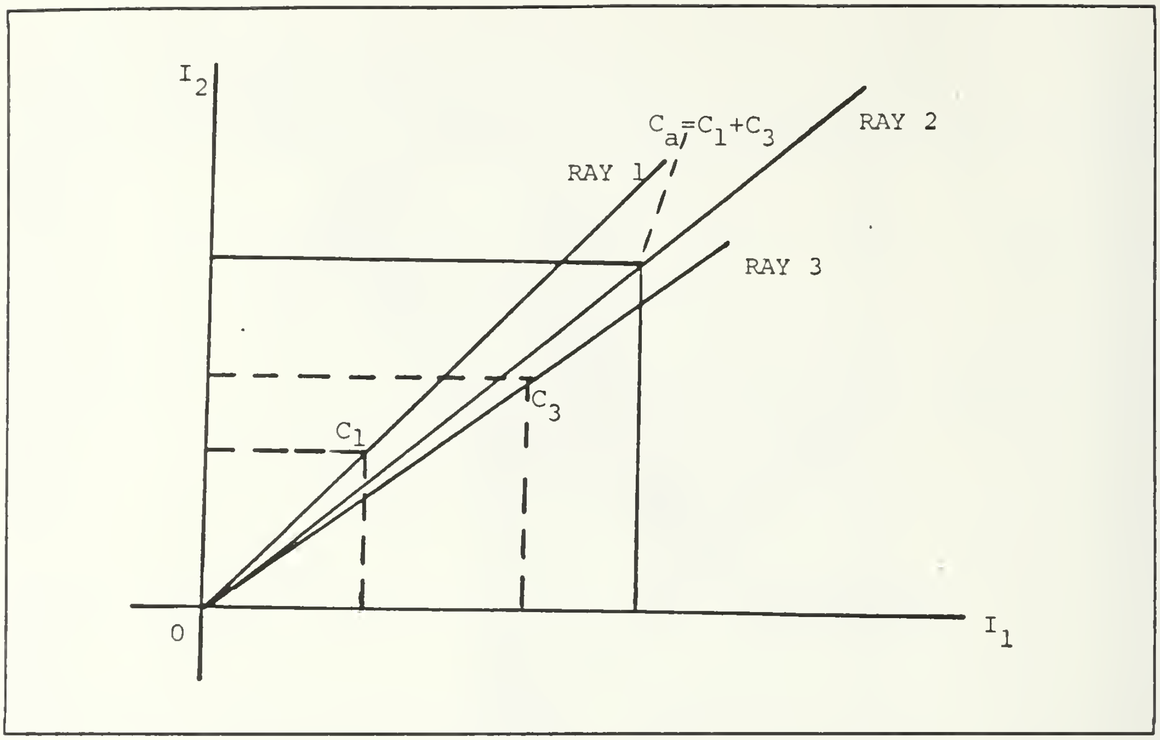


Figure 5.6 Comparison of Individual and Sum Ray Costing.

system more effective as a whole. Numerous parameters or variables, many of which are inter-related, come into play in evaluating system effectiveness. This section attempts to define some of these variables, as well as shed some light on the procedures a systems analyst might take in evaluating an ISCS.

System effectiveness can be defined as "a measure of the extent to which a system can be expected to achieve a set of specific mission requirements." When analyzing the effectiveness of a system one will note a great interdependency between the effectiveness of the system and the effectiveness of the mission the equipment supports. Though it is difficult to have an effective mission without the support of effective equipment, the analyst doing a systems effectiveness study will examine the impact of the equipment on mission effectiveness vice simply whether or not the equipment worked.

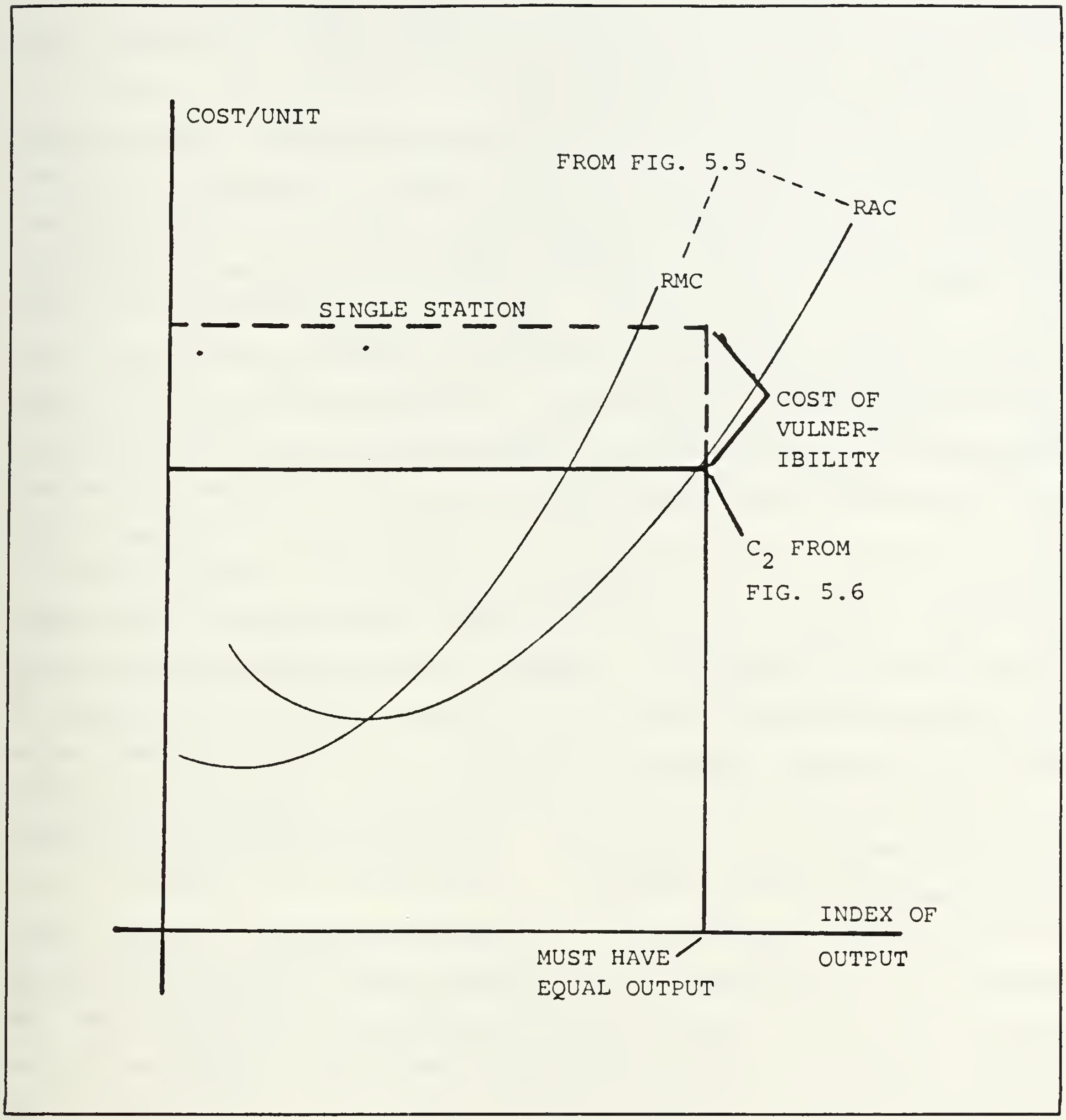


Figure 5.7 Vulnerability Costs.

This section will examine how to determine system effectiveness for the SNTI. The effectiveness of SNTI is a measure of the expected adequacy of the services provided in an assumed operational environment.

In order to evaluate the adequacy of the system, we must define some of the critical elements that comprise SNTI

given the requirements on the system, along with some of SNTI's basic operating characteristics that are needed to judge the system's effectiveness.

SNTI is a single loop transmission system that employs digital voice encoding and Time Division Multiplexing (TDM) of data. The system is distributed over a single transmission carrier, a coaxial cable. With this system a distinction is usually made between three user categories. First is the telephone network. Standard telephone sets are used and are connected to stations via interface units. Each interface unit contains an encoder/decoder and code conversion circuits for signalling information. Users on board ship can also communicate with subscribers of the shore network. Next is the intercom network. These intercom units are equipped with voice inputs and outputs, call keys and signalling devices. These units allow communications with one or several users of the same network. Finally is what is termed a special interface. Interface boxes are used to allow interfacing with radio transmitters and receivers as well as allowing announcement amplifiers to be connected up to the system.

Generally speaking the system consists of two main parts: 1) the transmission, multiplexing and demultiplexing subsystems which includes the connecting stations and the master stations; and 2) the user stations, each having its own interface for connection to SNTI.

The two independent master stations (at a minimum) provide supervisory control for all system terminals that are interfaced through connecting stations. They also generate the signals essential for TDM operation. The master station's continuous supervisory control ensures fault detection and location and provides for fault display on an associated teleprinter or CRT. They also initiate automatic reconfiguration in event of loop interruption.

Each connecting station can accept up to 16 user terminals, however, there is no user terminal that combines all functions. Therefore, watch stations requiring access to multiple IC systems and external radio will have a number of terminal devices. The purpose of these stations is to provide the users with an information input/output facility, allowing signalling and information to be introduced into and taken out of the multiplex.

At present, SNTI uses a 50-ohm coaxial cable that is duplicated to ensure that in the event of cable breakage the coax loop can be restored via reconfiguration. The second cable is for this purpose. Larger ships may have more than two cables.

Given this quick review of SNTI, we now look at the system with respect to the requirements of an integrated shipboard communications system. Systems effectiveness analysts, after careful review of previous studies and planning efforts by the Services/Agencies and the TRI-TAC Office, have identified 16 general elements for use in evaluating system effectiveness. See [Ref. 11]. These elements are intended to be reasonably exhaustive and independent of each other. These elements or Measures of Effectiveness (MOEs) can be divided into four groups and a hierarchal structure can be formed as shown in Table 8 .

This thesis will now examine the effectiveness of SNTI with respect to the MOEs provided. The U.S. Navy's interest in SNTI is based on the systems ability to perform in a worst case scenario. This means performance in a wartime scenario or hostile environment and how well can a ship perform its mission under such conditions. It's against this background that SNTI effectiveness will be evaluated. The ability of SNTI to meet each MOE will be examined on a one to one basis starting with Communications Measures.

TABLE 8

MEASURES OF EFFECTIVENESS

System Effectiveness

Communication Measures

Grade of Service, GOS
Information Quality, IQ
Speed of Service, SOS
Call Placement Time, CPT
Service Features, SF
Lost Message Rate, LMR
Spectrum Utilization, SU

Stability Measures

Index of Survivability (overt),IS
Index of Survivability (jamming), IS
Index of Availability, IA
Interrupt Rate, IR

Reorganization Measures

Transportability, T
Mobility, M
Ease of Reconfiguration, EOR
Ease of Transition, EOT
Interoperability, I

Security Measures

Enemy's ability to exploit our communications.

GOS is an estimate of the probability that a request for communication service (placement of a call) will be blocked. It is computed for the time period of greatest demand. In evaluating system effectiveness a defining equation was developed:

$$GOS = f(T, C, R, A, D) \qquad \text{(eqn 5.3)}$$

T = Traffic volume or demand by type of service - telephone, intercom ,radio or announcing.

C = Channel capacity; SNTI offers either 120 or 240 channels.

R = Alternative routing capability; with SNTI this depends on system configuration.

A = Call arrival probability distribution. For SNTI telephones this means a group of channels with random access (Poisson distribution) are allocated and a caller finds a free channel. If all channels are busy he receives a busy signal. For all other services the connection facilities are defined by a matrix representing the interconnecting grid(s) as laid down in the system specifications. The master station allows for connection to the matrices by creating the subnetworks conforming to the grid(s).

D = Call or message duration; the value will probably result from a review of historical data.

The second MOE is IQ which represents the degree of accuracy with which the received signal compares to the original transmitted signal. It may be defined as:

$$IQ = f(S,W,K,D,P,M) \qquad \text{(eqn 5.4)}$$

S = Signal to noise ratio; a function of P, W and the chosen transmission medium.

P = Power level; as required or selected for the evaluation.

W = Bandwidth; as required or selected for the evaluation.

K = Crosstalk (dB); varies with transmission medium and the environment.

D = % of distortion; based on transmission medium and environment.

M = Modulation scheme and coding; SNTI is a digital system using TDM with frames with 128 time slots on a bit by bit basis. 120 slots equate to 120 channels and the

remaining eight bits form a frame block for frame alignment and signalling.

The weight given IQ can vary depending on the transmission service selected. Also the values assigned to the variables can differ greatly based on the service involved and the parameters selected. Therefore it is important to distinguish which service for information transfer is being utilized.

Next is SOS, the expected time that a message requires to move through the network from the last bit out of the sending terminal to the last bit in to the receiving terminal. This can be defined as:

$$SOS = f(S, R, D, Pl, P) \qquad \text{(eqn 5.5)}$$

S = Sampling rate; determined by a common clock whose frequency is a multiple of the bit rate of a given channel.

R = Routing plan; varies with system design as it depends on the size of the loop, number of stations, etc.

D = Dialing method; which varies with type of service selected.

Pl = Precedence level; relates to urgency of call, priority assigned to announcing channels etc.

P = Processor speed; SNTI has durations of 244 nanosec for bit rate, 31.2 usec for frame repetition rate, 250 usec for frame alignment repetition rate and 32 millisec for multi-frame repetition rate.

CPT follows. Simply put this is the time required to establish a connection or complete a circuit between callers. This can be defined as:

$$CPT = f(A, P, H) \qquad \text{(eqn 5.6)}$$

A = Access time; which for telephone service depends on the availability of a free channel. For the other services access is a function of the matrix capability. The matrix may employ manual access (diode matrix) or it may be implemented by means of software.

P = Processor speed; defined for SOS.

H = Human factor; how well does the operator perform at his console.

Service features are a qualitative assessment of the services available. These features are usually a function of the console that interfaces with a system rather than the system hardware itself. Some features falling under Communications Measures are: single instrument access and selection, single access calling, busy circuit identification, incoming call alert, identification of calling party, urgency of call indicator, call override, call hold, break-in, conference calling and volume/brightness control. An equation defining SF would be a function of those features considered essential for system effectiveness.

The LMR pertains more to hardcopy message traffic vice voice transmissions. Its impact on system effectiveness with regards to SNTI would be negligible so it can be excluded as an MOE.

Another element, SU, can also be excluded. Though vital to the analysis of communications system effectiveness it is not really a valid MOE for SNTI, which only has an interface capability with a ships radio transmitters and receivers. SNTI itself does not contain the hardware that this MOE evaluates.

The next area to review under the MOE hierarchy is that of Stability Measures. The IS, for both overt attack and for jamming, basically re-evaluates the GOS sustained by the system after being subjected to an attack or to jamming. It compares the average number of calls completed after the

attack or jamming to the average number of calls prior to either incident.

In order to maintain a high level of GOS the design of the system includes redundancy. SNTI is designed to incorporate two or more master stations, up to 240 connecting stations each allowing for up to 16 users to be connected to the system and two coxial cables as alluded to earlier. The flexible design of the system allows for maximum separation between the stations and between the cables to minimize the damage to the system from a single hit. Also, because the transmission circuit operates on a digital basis, the signals are immune to electromagnetic interference; besides presenting no source of interference to the other shipboard radio equipment.

The next MOE to be examined is the IA, which can be simply expressed as the ratio of the up-time of a system to the total time required of the system. Part of evaluating IA includes a determination of the Mean Time Between Failures (MTBF). To help ensure a high MTBF a solid state design is used in designing SNTI. The system is constantly tested and any fault detected is immediately printed on the teleprinter or displayed on the CRT that is associated with a master station. When a fault is detected in the loop (interrupt or cutoff) the master station emits a signal to trigger an automatic reconfiguration procedure, restoring the transmission.

When a fault occurs in the active master station the standby one takes over immediately. Also, the continuous monitoring system displays failures at the circuit board module level thus allowing for quick repairs of the faulty part. Plus, additional programs can be implemented for bringing fault finding down to a component level. All these features help maximize system up-time thereby increasing the system IA. One other point worthy of note, is that SNTI

meets naval environmental specifications with respect to temperature, humidity, salt spray, shock and corrosion.

Next, the IR measures the percentage of calls that are interrupted inadvertently by the system for reasons other than pre-emption. This is a measurement of either the probability of losing bit synchronization, system timing and crypto synchronization or signal fading. The value of the former would be based on a statistical analysis of the bit error rate, clock failures, TDM weaknesses, etc. The latter would entail a more subjective analysis based on selected parameters such as frequency, power and bandwidth as well as environmental conditions. Most of the analysis concerning signal fading would deal with the radio transmitters and receivers that SNTI interfaces with rather than the system itself.

A third group of MOEs to examine come under Reorganization Measures. The first MOE in this group is Transportability, which is the ease with which the network or parts thereof can be moved. With respect to SNTI this MOE is negligible. Since SNTI is designed to be a permanent installation aboard ship the significance of this MOE is severely diminished.

The same can be said of the next MOE, Mobility. Its impact is also negligible. It's worth noting however, that SNTI's design is characterized by the use of interface circuits common to all types of users and the use of microprocessors in all stations. These two factors combine to give optimum flexibility and permit the system to be adapted to a large extent to the specifications and installation limitations of various ship types. Its flexibility also makes it easy to install and it's designed to provide a major savings on cable.

Ease of Reconfiguration is one of the most important MOEs and it is concerned with measuring the ability of a

system to expand, contract and reorganize to meet subscriber demands. The impact of adding or deleting another station to the system has little or no impact on system performance. Another distinct assest of this type of network is its isolation from the user devices except for interface compatibility. This allows for user devices to evolve with concern only for interface compatibility and not for the hardware (and to some extent the software) in the network itself.

Next is Ease of Transition which measures the inherent ability of a system's design that allows for major modification without system degradation. The amount of down-time and/or system degradation resulting from a major modification would require an in-depth analysis of the impact of each modification to SNTI. However, SNTI easily lends itself to all types of connections that may be required onboard ship as a result of a modification; point-to-point, conference or multi-point, announcement and information collection. The system is adaptable, so it can be altered as well as expanded with a minimum of cost and its flexibility allows for many modifications without any changes in the hardware.

The last MOE in this group, Interoperability, measures the degree to which a system can interface with external systems. Since SNTI can interface with radio transmitters and receivers in can therefore interface with external systems. However, its ability to do so effectively is only as good as the radio equipment it interfaces with. As such the effect of this MOE on evaluating SNTI is not truly reflective of the system itself.

The last group is under the heading of Security Measures which is beyond the scope of this paper. But it is worth mentioning that SNTI does have a secure voice capability and as stated before, it has the advantage of being a digital system with respect to electromagnetic interference.

In conclusion, it should be noted that the effectiveness of each MOE is based on the accuracy of the values assigned to the variables that make up the function defining each MOE. These values are often subjective and can vary greatly, not only from system to system but within a single system, such as when the MOE can be used to measure specific features of that system.

VI. THE EVALUATION OF SNTI

Now that the capabilities and operating characteristics of SNTI have been presented, it's time to evaluate its performance against the requirements, functions and performance standards that defined an ideal ISCS.

A. SUMMARY

The previous chapter defined the models, equations and techniques that design analysts and systems analysts might use in evaluating certain aspects of SNTI. The methods necessary for analyzing vulnerability costs and system effectiveness extend well beyond the scope of this thesis.

Though obviously lacking the necessary data to form a quantitative evaluation and precise solution with respect to vulnerability costs, it is this author's observation that the cost of vulnerability would tend to support separate single production, rather than joint production (all communication through one connecting station with only one master station). When defined in terms of an ISCS this indicates it is more beneficial to have dispersed communication requirements. With respect to SNTI, this means a system designed with multiple connecting stations and at least on back-up master station.

The preceding statement tends to support the design features of SNTI. With its numerous stations, redundant cabling and integrated terminals, no communication requirement is limited to a single route or source. Though system, or production, costs will increase with the addition of more stations, (though only to a certain point, before beginning to decrease) the standardization of SNTI components helps to reduce costs.

While lacking the required data needed for a concise solution to the question of system effectiveness, it is still possible to predict a likely outcome. This can be accomplished by comparing SNTI against the requirements of an ideal system.

The reason SNTI is not matched against an ideal system with respect to the MOEs presented is that SNTI would always lose. The MOEs are used to provide an indication of a specific systems level of output. In this case, the measure of performance for SNTI would be matched against the output of an ideal system. For SNTI to have a higher level of performance or output than the ideal system is obviously an impossible task.

In order to gain a better perspective on how well SNTI matches up against other IC systems see Table 9 .

We begin with examining how well SNTI did in eliminating known IC problems. For a review of these problems refer to Table 3 . As the capabilities of SNTI are matched against the desired functions and capabilities of the ideal system, see Table 4, it is clear that SNTI has eliminated these IC problems. Though, to what degree they have been eliminated would be a goal of an in-depth analysis of system effectiveness using the MOEs presented earlier.

Speed and Simplicity. This is an advantage of SNTI due to the design of the system. A digital multiplex (TDM) is more easily implemented than analog (FDM). In conjunction with this, Delta Modulation is simpler to implement than the other probable choice - Pulse Code Modulation. Additionally, the selection of baseband coax cable allows for greater transmission speed than the other alternative, broadband. Finally, the console face is designed with a minimum number of buttons and switches.

TABLE 9

COMPARISON OF IC SYSTEMS

PRODUCTS \ ATTRIBUTES	OPERATIONAL REQUIREMENTS																RANGE			EXPLOITATION		
	SINGLE ACCESS	SINGLE ACTION CALLING	BUSY CIRCUIT ID	INCOMING CALL ALERT	CALLER IDENTITY	CALL URGENCY	CALL OVERRIDE	CALL HOLD	HUNT NOT BUSY	BREAK IN	CONFERENCE	PRIVACY	SECURE VOICE	RADHAZ PROTECT 1/	STANDARDIZATION	SURVIVABILITY	SPEED/SIMPLICITY	INTEGRATION	FLEXIBILITY	ANTI-JAM	LOW PROB INTERCEPT	NOTES
MULTI-CAPABILITY VOICE SYSTEMS																						
IVCS AN/STC-1	X	P		X		X	X		X	X	X	X		C	X	C	X	P	P	C	P	2/
IVCS AN/STC-2	X	P		X	P	X	X	P	X	X	X	X		C	X	C	X	P	P	C	P	2/
• DVMS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	P	2/, 3/
• ICT	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X	P	2/, 3/
• S.N.T.I. 120/240	X	X		X							X	X		P	X		X			X	X	
• MCS 2000	X	X	X	X						X	X	X	X		X		X			C	X	2/

X – FULL CAPABILITY

P – PARTIAL CAPABILITY

C – POSSIBLE CRITICAL DEFICIENCY/ VULNERABILITY

• – INDICATES CURRENT DEVELOPMENT/ INVESTIGATION

1/ – RADHAZ PROTECTION CONSIDERS EMP EFFECTS AND SUSCEPTIBILITY OF TERMINAL DEVICES TO RADIOLOGICAL CONTAMINATION.

2/ – MULTI-CAPABILITY VOICE SYSTEMS ARE LPI EXCEPT WHEN TRANSMITTING ON EXTERNAL COMM SYSTEM.

3/ – CURRENTLY PROJECTED CAPABILITY

An obvious way to speed up transmissions, reduce the actions required to complete the call, provide more freedom of movement and lessen the number of buttons and switches required is use speech recognition. The possibility of using a voice activated terminal access has been reviewed recently. It was concluded that the fluctuation in an operator's voice due to increased stress and tension, along with possible programming difficulties arising from the need for an operator to change consoles quickly made the concept infeasible at the present time.[5]

Integration. Though not in agreement with Table 9, the conclusion is that SNTI's design helps meet this requirement. The system is capable of multi-media access. The console operator has access to an intercom network, announcing/alarm network, telephone system and radio net. Plus communication can be conducted on all circuits via a single microphone.

Flexibility. Since SNTI uses standard hardware and programable software (diode matrix circuit boards and directory memory) it can be adapted easily to meet the IC needs of different classes of ships. This also allows for shipboard personnel to make configuration changes when communication requirements change. Again, this is in disagreement with Table 9 .

Standardization. SNTI uses the same basic hardware and design characteristics for each installation. There is no requirement for special equipment due to differences in system size and capacity. SNTI's phone network is compatible with the PABX.

Communications Configuration Capability. Again, this is similar to the flexibility requirement. The system is programmable, so each console can be tailored to the

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[5] This opinion was provided in a phone conversation between Mr. Gail Borden of Human Performance Research, Inc. and this author in January 1986.

operator's needs. It is also makes it quite simple for operators to switch consoles.

System Reconfiguration. The system's loop configuration makes it easy to add/delete stations. Connecting station design makes it easy to add/delete users; up to 16 per station.

Survivability. SNTI's design incorporates two or more master stations (at least one in standby) and, at a minimum, at least a dual loop configuration for redundancy. Improved ship design and installation features, such as a Kevlar superstructure and shock mounting of equipment, also enhances survivability.

Protection from Radiation Hazards (RADHAZ). The 50 Ohm coaxial cable provides for improved immunity against low frequency electromagnetic interference. The loop configuration also reduces cabling requirements which further decrease insulation and ducting needs.

Emergency Power. SNTI is provided with a back-up battery system for both its master and connecting station(s).

Maintenance. SNTI has a continuous, self-monitoring capability. It has a built-in-test system and a teleprinter(s) that provides system status reports, fault indicators and station malfunction alerts. The system is designed for ease of maintenance down to the line replacement level and can be programmed for repair down to the component level.

Environmental Considerations. SNTI meets the U.S. Navy's environmental specifications with respect to temperature, humidity, salt spray and, shock and corrosion.

Secure Voice. SNTI is secure voice capable. This is in disagreement with Table 9 .

Privacy. SNTI does provide for privacy on its IC circuits.

Monitoring Capability. SNTI does provide a monitoring capability.

With respect to the operational capabilities of SNTI, the determination as to whether or not the requirement has been met is fairly straightforward. The following operational requirements (functions) have been satisfied:

1. Single Access
2. Single Action Calling
3. Incoming Call Alert
4. Single Action Transmission
5. Conference Call
6. Instrument Design
7. Brightness Control
8. Volume Control

At the present time the following capabilities (features) have not been met by SNTI:

1. Busy Circuit Indication
2. Identity of Calling Party
3. Identify Urgency of Call
4. Call Override
5. Break-in
6. Call Hold
7. Hunt-not-Busy

B. CONCLUSION

In satisfying the fundamental design requirements of an ideal communication system, SNTI performs well. The three primary requirements are speed and simplicity, integration and flexibility. Though, in disagreement with the view expressed in Table 9, SNTI appears to match up well in these areas. It is easy to design a system to satisfy the speed, integration and flexibility requirements, but it is more difficult to do while simultaneously keeping the design and operation simple as well. Through the use of such operating

parameters and characteristics as baseband coaxial cable, delta modulation, etc., SNTI has achieved an excellent balance.

When compared to the operational requirements of the ideal system SNTI does not fair as well. This is especially true from the user's point of view. While SNTI did extremely well meeting the functional requirements, to the user, these are transparent. For instance, the effect of the multiplex or the use of DM cannot be seen. However, the inability to identify the source of a call and determine it's urgency is a serious limitation.

When examining this system from the point of view of a system designer, and even a systems analyst, SNTI appears to be more than adequate. In addition, SNTI has an excellent potential for growth and improvement.

The user, however, sees problems. Though the lack of such a simple item as a break-in capability may appear insignificant to the system designer, to the user it can present a major difficulty. Without this capability, the user could experience a serious delay in attempting to get a call through. In a hostile situation, where time is of the essence, this could have disastrous effects.

While the use of baseband coaxial cable may increase speed (compared to broadband), communication delays will occur because of the lack of a few features that are not incorporated into console capabilities.

Therefore, more work is required on this system. Having satisfied the fundamental requirements of an ISCS, the most difficult and demanding tasks are passed. More of the operational requirements given earlier need to be satisfied. The console operator needs as many of these features as possible at his fingertips, without being overwhelmed with buttons, switches and dials. Incorporating these additional features into SNTI would make it a complete, if not ideal, system.

Installing SNTI aboard a FFG-7 or DDG-51 as a test platform would be extremely beneficial. Everyday use of the system would enable the operators to not only identify the features they need, but prioritize them as well. Then, these additional features can be integrated into SNTI, hopefully, without degrading system performance in other areas.

APPENDIX A

SUBSCRIBER REQUIREMENTS FOR A DDG-51 ISCS

This appendix contains descriptions of the subscriber (user) requirements of individual console operators and C^2 personnel [Ref. 3]. The listings are not intended to provide a comprehensive account of subscriber requirements. They are intended to provide a basis for a general understanding of the scope of subscriber requirements; keeping in mind the tremendous demand this can place on an ISCS.

As mentioned previously, Readiness Condition I places the greatest demand on an ISCS due primarily to the increase in the number of subscribers and their associated communication requirements. These tables are provided to assist the reader in grasping the enormous communication tasking and system coordination that fighting a ship requires.

TABLE 10

COMMANDING OFFICER (CIC POSITION)

<u>Interior Communication (IC) Subscribers</u>

Tactical Action Officer
Combat System Coordinator
Ownship Display Controller
Tactical Information Coordinator
Electronic Warfare Supervisor
AAW Coordinator
ASUW Coordinator
Engagement Planning Supervisor
Launch Control Operators
ASW coordinator
Anti-Submarine Air Controller

Officer-of-the-Deck
Engineering Officer-of-the-Watch
Secondary Engineering Control
Damage Control Central
Secondary Damage Control
Helicopter Control Station
Ships Signals Exploitation Space
Main Communications
Electronic Maintenance Officer

<u>Announcing Systems</u>

General Announcing
Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 11

TACTICAL ACTION OFFICER

IC Subscribers

Commanding Officer - CIC position
Combat Systems Coordinator
Ownship Display Controller
Tactical Information Coordinator
Electronic Warfare Supervisor
AAW Coordinator
Air Intercept Controller
ASUW Coordinator
Engagement Planning Supervisor
Launch Control Operators
ASW Coordinator
Anti-Submarine Aircraft Controller

Commanding Officer - Bridge position
Commanding Officer - Cabin
Officer-of-the-Deck
Engineering Officer-of-the-Watch
Secondary Engineering
Damage Control Central
Secondary Damage Control
Helicopter Control Station
Main Communications
Electronics Maintenance Officer

Announcing Systems

General Announcing
Threat Announcing

Exterior Communications

Required

TABLE 12

COMBAT SYSTEM COORDINATOR

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Ownship Display Controller
Tactical Information Coordinator
Radar System Controller
AAW Coordinator
Missile System Supervisor
Air Intercept Controller
ASUW Coordinator
Engagement Planning Supervisor
ASW Coordinator
Acoustic Track Supervisor/Underwater FC Operator

Combat System Casualty Control - Supervisor
Radar Rooms
Computer Room(s)

<u>Announcing System</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 13

OWNSHIP DISPLAY CONTROLLER

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Combat System Coordinator
Tactical Information Coordinator
EW Supervisor

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 14

TACTICAL INFORMATION COORDINATOR

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Combat System Coordinator
Ownship Display Controller
Radar System Controller
Identification Supervisor
EW Supervisor
EW Console Operator
AAW Coordinator
Air Intercept Controller
ASUW Coordinator
Surface Warfare Supervisor
Engagement Planning Supervisor
Extended Surveillance Operator
ASW Coordinator
Anti-Submarine Aircraft Controller

<u>Announcing Systems</u>

Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 15

RADAR SYSTEM CONTROLLER

IC Subscribers

Combat System Coordinator
Tactical Information Coordinator
EW Supervisor
AAW Coordinator
Missile System Supervisor
ASW Coordinator

Combat System Casualty Control Room
Radar Rooms
Computer Room(s)

Announcing Systems

Not Required

Exterior Communications

Not Required

TABLE 16

IDENTIFICATION SUPERVISOR

IC Subscribers

Tactical Information Coordinator
EW Supervisor
EW Console Operator
AAW Coordinator
Air Intercept Controller
ASUW Coordinator
Surface Warfare Supervisor
ASW Coordinator
Anti-Submarine Aircraft Controller

Announcing Systems

Not Required

Exterior Communications

Required

TABLE 17

ELECTRONIC WARFARE SUPERVISOR

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Ownship Display Controller
Tactical Information Coordinator
Radar System Controller
Identification Supervisor
EW Console Operator
AAW Coordinator
ASUW Coordinator
Surface Warfare Supervisor
ASW Coordinator

EW Equipment Room(s)
Ships Signal Exploitation Space

<u>Announcing System</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 18

ELECTRONIC WARFARE CONSOLE OPERATOR

<u>IC Subscribers</u>

Tactical Information Coordinator
Identification Supervisor
EW Supervisor
AAW Coordinator

<u>Announcing Systems</u>

Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 19

ANTI-AIR WARFARE COORDINATOR

IC Subscribers

Commanding Officer - CIC position
Tactical Action Officer
Combat System Coordinator
Tactical Information Coordinator
Radar System Controller
Identification Supervisor
EW Supervisor
EW Console Operator
Missile System Supervisor
Air Intercept Controller
ASUW Coordinator
Gunfire Control Supervisor
ASW Coordinator

Commanding Officer - Bridge position
Officer-of-the-Deck
Helicopter Control Station
Main Communications
VLS Control
CIWS Control

Announcing Systems

Threat Announcing

Exterior Communications

Required

TABLE 20

AIR INTERCEPT CONTROLLER

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Combat System Coordinator
Tactical Information Coordinator
Identification Supervisor
AAW Coordinator
Missile System Supervisor
ASUW Coordinator
ASW Coordinator
Anti-Submarine Aircraft Controller

Helicopter Control Station
Main Communications

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 21

MISSILE SYSTEM SUPERVISOR

<u>IC Subscribers</u>

Combat System Coordinator
Radar System Controller
AAW Coordinator
Air Intercept Controller
ASW Coordinator

VLS Control
CIWS Control

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 22

ANTI-SURFACE WARFARE COORDINATOR

<u>IC Subscribers</u>

Commanding Officer - CIC position
Tactical Action Officer
Combat System Coordinator
Tactical Information Coordinator
Radar System Controller
Identification Supervisor
EW Supervisor
AAW Coordinator
Air Intercept Controller
Surface Warfare Supervisor
Gunfire Control Supervisor
Engagement Planning Supervisor
Extended Surveillance Supervisor
Launch Control Operators
Digital DRT Plotters
ASW Coordinator
Anti-Submarine Aircraft Controller

Commanding Officer - Bridge position
Officer-of-the-Deck
Main Communications
Surface Radar Console Operator
Ships Signal Exploitation Space

<u>Announcing Systems</u>

Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 23

SURFACE WARFARE SUPERVISOR

<u>IC Subscribers</u>

Tactical Information Coordinator
Identification Supervisor
EW Supervisor
ASUW Coordinator
Extended Surveillance Operator
Digital DRT Operators

Surface Radar Console Operator
Lookouts

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 24

GUNFIRE CONTROL SUPERVISOR

<u>IC Subscribers</u>

AAW Coordinator
ASUW Coordinator

Gun Mount Control

<u>Announcing System</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 25

ENGAGEMENT PLANNING SUPERVISOR

<u>IC Subscribers</u>

Commanding Officer - CIC position
Tactical Action Officer
Combat System Coordinator
Tactical Information Coordinator
ASUW Coordinator
Extended Surveillance Operator
Launch Control Operators

VLS Control

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 26

EXTENDED SURVEILLANCE OPERATOR

<u>IC Subscribers</u>

Tactical Information Coordinator
ASUW Coordinator
Surface Warfare Supervisor
Engagement Planning Supervisor
Anti-Submarine Aircraft Controller

<u>Announcing System</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 27

LAUNCH CONTROL OPERATORS

IC Subscribers

Commanding Officer - CIC position
Tactical Action Officer
ASUW Coordinator
Engagement Planning Supervisor

VLS Control

Announcing Systems

Not Required

Exterior Communications

Not Required

TABLE 28

DIGITAL DEAD RECKONING TRACER PLOTTERS

IC Subscribers

ASUW Coordinator
Surface Warfare Supervisor
ASW Coordinator
Acoustic Track Supervisor/Underwater FC Operator

Lookouts

Announcing Systems

Not Required

Exterior Communications

Not Required

TABLE 29

ANTI-SUBMARINE WARFARE COORDINATOR

<u>IC Subscribers</u>

Commanding Officer - CIC position
Tactical Action Officer
Combat Systems Coordinator
Tactical Information Coordinator
Identification Supervisor
EW Supervisor
AAW Coordinator
Air Intercept Controller
Missile System Supervisor
ASUW Coordinator
Acoustic Track Supervisor/Underwater FC Operator
Anti-Submarine Aircraft Controller
Plotters

Officer-of-the-Deck
Sonar Control - Acoustic Supervisor
Main Communications
Helicopter Control Station

<u>Announcing System</u>

Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 30

ACOUSTIC TRACK SUPERVISOR/UNDERWATER FC OPERATOR

IC Subscribers

Combat System Coordinator
ASW Coordinator
Anti-Submarine Aircraft Controller
Plotters

Sonar Control - Acoustic Supervisor
Torpedo Rooms
Expendable Bathythermograph (XBT) Room

Announcing System

Not Required

Exterior Communications

Required

TABLE 31

ANTI-SUBMARINE AIRCRAFT CONTROLLER

IC Subscribers

Commanding Officer - CIC position
Tactical Action Officer
Tactical Information Coordinator
Identification Supervisor
Air Intercept Controller
ASUW Coordinator
ASW Coordinator
Acoustic Track Supervisor/Underwater FC Operator

Officer-of-the-Deck
Helicopter Control Station
Sonar Control - Acoustic Supervisor
Surface Radar Console Operator

Announcing System

Not Required

Exterior Communications

Required

TABLE 32

SONAR CONTROL - ACOUSTIC SUPERVISOR

IC Subscribers

ASW Coordinator
Acoustic Track Supervisor/Underwater FC Operator
Anti-Submarine Aircraft Controller

Hull Sonar System Operators (HSSOs)
Towed Sonar System Operator (TSSO)
Acoustic Sonar Operator (ASO)
Lookouts
Sonar Equipment Room(s)

Announcing Systems

Threat Announcing

Exterior Communications

Required

NOTE:
The subscriber requirements of HSSOs, TSSO and ASO are identical to those listed above for the Sonar Control - Acoustic Supervisor.

TABLE 33

COMMANDING OFFICER - BRIDGE POSITION

<u>IC Subscribers</u>

Tactical Action Officer
AAW Coordinator
ASUW Coordinator
Surface/Subsurface Warfare Coordinator

Engineering Officer-of-the-Watch
Damage Control Central
Helicopter Control Station
Secondary Engineering Control
Secondary Damage Control

<u>Announcing Systems</u>

General Announcing

<u>Exterior Communications</u>

Required

TABLE 34

OFFICER-OF-THE-DECK

<u>IC Subscribers</u>

Commanding Officer - CIC position
Commanding Officer - Cabin
Tactical Action Officer
AAW Coordinator
ASUW Coordinator
ASW Coordinator
Anti-Submarine Aircraft Controller
Engineering Officer-of-the-Watch
Damage Control Central
Helicopter Control Station
Main Communications
Electronic Maintenance Officer
Combat System Casualty Control
Signal Bridge
Executive Officer - Stateroom/Office
Secondary Engineering Control
Secondary Damage Control

<u>Announcing Systems</u>

General Announcing

<u>Exterior Communications</u>

Required

TABLE 35

SURFACE RADAR CONSOLE OPERATOR

<u>IC Subscribers</u>

ASUW Coordinator
Surface/Subsurface Warfare Coordinator
Surface Warfare Supervisor
Anti-Submarine Aircraft Controller

Helicopter Control Station
Lookouts

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Not Required

APPENDIX B

SUBSCRIBER REQUIREMENTS FOR A FFG-7 ISCS

This section contains descriptions of the subscriber (user) requirements of individual console operators and C^2 personnel. The listings are not intended to provide a comprehensive account of subscriber requirements. They are intended to provide a basis for a general understanding of the scope of subscriber requirements; keeping in mind the tremendous demand this can place on an ISCS.

TABLE 36

COMMANDING OFFICER (CIC POSITION)

Interior Communication (IC) Subscribers

Tactical Action Officer
Weapons Control Officer
Electronic Warfare Supervisor
Track Supervisor
ASW Evaluator
Anti-Submarine Air Controller
Air Intercept Controller

Officer-of-the-Deck
Engineering Officer-of-the-Watch
Secondary Engineering Control
Damage Control Central
Secondary Damage Control
Helicopter Control Station
Radio Central (Main Communications on DDG-51)
Electronic Maintenance Officer

Announcing Systems

General Announcing
Threat Announcing

Exterior Communications

Required

TABLE 37

TACTICAL ACTION OFFICER

<u>IC Subscribers</u>

Commanding Officer - CIC position
Weapons Control Officer
Electronic Warfare Supervisor
Air Intercept Controller
Anti-Submarine Aircraft Controller
Track Supervisor
ASW Evaluator
Sonar Supervisor

Combat System Casualty Control - Supervisor
Radar Rooms
Computer Room(s)

Commanding Officer - Bridge position
Commanding Officer - Cabin
Officer-of-the-Deck
Engineering Officer-of-the-Watch
Secondary Engineering
Damage Control Central
Secondary Damage Control
Helicopter Control Station
Radio Central
Electronics Maintenance Officer

<u>Announcing Systems</u>

General Announcing
Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 38

WEAPONS CONTROL OFFICER

IC Subscribers

Commanding Officer
Tactical Action Officer
Weapons Console Operators
Air Intercept Controller
Anti-Submarine Aircraft Controller
Track Supervisor
ASW Evaluator
Sonar Supervisor

Announcing System

Not Required

Exterior Communications

Required

TABLE 39

TRACK SUPERVISOR

IC Subscribers

Commanding Officer
Tactical Action Officer
Weapons Control Officer
Air Detector Tracker
Surface Detector Tracker
EW Supervisor
EW Console Operator
Air Intercept Controller
ASW Evaluator
Anti-Submarine Aircraft Controller

Announcing Systems
Not Required

Exterior Communications

Required

TABLE 40

ELECTRONIC WARFARE SUPERVISOR

<u>IC Subscribers</u>

Commanding Officer
Tactical Action Officer
Weapons Control Officer
Surface Detector Tracker
Air Detector Tracker
Track Supervisor
EW Console Operator
ASW Evaluator
Anti-Submarine Aircraft Controller

EW Equipment Room(s)
Combat System Casualty Control Room

<u>Announcing System</u>

Required

<u>Exterior Communications</u>

Required

TABLE 41

ELECTRONIC WARFARE CONSOLE OPERATOR

<u>IC Subscribers</u>

Tactical Action Officer
Surface Detector Tracker
Air Detector Tracker
Track Supervisor
EW Supervisor
DRT Plotters

<u>Announcing Systems</u>

Threat Announcing

<u>Exterior Communications</u>

Required

TABLE 42

AIR INTERCEPT CONTROLLER

IC Subscribers

Commanding Officer
Tactical Action Officer
Weapons Control Officer
Track Supervisor
EW Supervisor
Anti-Submarine Aircraft Controller

Helicopter Control Station
Radio Central

Announcing Systems

Not Required

Exterior Communications

Required

TABLE 43

AIR DETECTOR TRACKER

IC Subscribers

Tactical Action Officer
Weapons Control Officer
ASW Evaluator
EW Supervisor
EW Console Operator
Air Intercept Controller
Anti-Submarine Aircraft Controller
Track Supervisor

Announcing Systems

Not Required

Exterior Communications

Required

TABLE 44

SURFACE DETECTOR TRACKER

<u>IC Subscribers</u>

Tactical Action Officer
Weapons Control Officer
ASW Evaluator
EW Supervisor
EW Console Operator
Anti-Submarine Aircraft Controller
DRT Plotters
Track Supervisor

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 45

WEAPONS CONTROL CONSOLE OPERATORS

<u>IC Subscribers</u>

Tactical Action Officer
Weapons Control Officer
other Weapons Control Console Operators
Air Detector Tracker
Surface Detector Tracker
Track Supervisor

Launcher Control
Gun Mount

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 46

DEAD RECKONING TRACER PLOTTERS

<u>IC Subscribers</u>

Tactical Action Officer
Weapons Control Officer
ASW Evaluator
Track Supervisor
Surface Detector Tracker
EW Console Operator

Sonar Supervisor
Lookouts

<u>Announcing Systems</u>

Not Required

<u>Exterior Communications</u>

Not Required

TABLE 47

ANTI-SUBMARINE WARFARE EVALUATOR

IC Subscribers

Commanding Officer - CIC position
Tactical Action Officer
Weapons Control Officer
Track Supervisor
EW Supervisor
Air Intercept Controller
Anti-Submarine Aircraft Controller
Plotters

Officer-of-the-Deck
Sonar Control - Sonar Supervisor
Radio Central
Helicopter Control Station

Announcing System

Threat Announcing

Exterior Communications

Required

TABLE 48

SONAR SUPERVISOR

IC Subscribers

Tactical Action Officer
ASW Evaluator
Anti-Submarine Aircraft Controller
Weapons Control Officer
Plotters

Torpedo Rooms
Expendable Bathythermograph (XBT) Room

Announcing System

Not Required

Exterior Communications

Required

TABLE 49

ANTI-SUBMARINE AIRCRAFT CONTROLLER

<u>IC Subscribers</u>

Commanding Officer - CIC position
Tactical Action Officer
Weapons Control Officer
Track Supervisor
Air Intercept Controller
EW Supervisor
ASW Evaluator

Officer-of-the-Deck
Helicopter Control Station
Sonar Control - Sonar Supervisor

<u>Announcing System</u>

Not Required

<u>Exterior Communications</u>

Required

TABLE 50

COMMANDING OFFICER - BRIDGE POSITION

<u>IC Subscribers</u>

Tactical Action Officer
Weapons Control Officer
ASW Evaluator

Engineering Officer-of-the-Watch
Damage Control Central
Helicopter Control Station
Secondary Engineering Control
Secondary Damage Control

<u>Announcing Systems</u>
General Announcing

<u>Exterior Communications</u>

Required

TABLE 51

OFFICER-OF-THE-DECK

<u>IC Subscribers</u>

Commanding Officer - CIC position
Commanding Officer - Cabin
Tactical Action Officer
Weapons Control Officer
ASW Evaluator
Anti-Submarine Aircraft Controller
Engineering Officer-of-the-Watch
Damage Control Central
Helicopter Control Station
Radio Central
Electronic Maintenance Officer
Combat System Casualty Control
Signal Bridge
Executive Officer - Stateroom/Office
Secondary Engineering Control
Secondary Damage Control

<u>Announcing Systems</u>

General Announcing

<u>Exterior Communications</u>

Required

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